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RAILWAY TRACK AND TRACK WORK.

By
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SECOND EDITION
Fully revised, and with Supplementary Chapters on "Signals and Interlocking" and "Street Railway Track."

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PREFACE TO THE SECOND EDITION.

In view of the importance of the railway track which carries the enormous railway traffic of the United States, and in view of the amount of engineering and technical work involved in the construction and maintenance of the track and its appurtenances, it may appear somewhat strange that the technical literature on the subject should be so limited as compared with that on other branches of railway engineering. This may be attributed largely to the fact that until within quite recent years, this department of railway service was considered to belong to the grade of skilled labor rather than to men of scientific and technical training. The book on "Track," written by Mr. Wm. B. Parsons in 1886, was practically the first book dealing with the subject from the engineering point of view, and written for the use of the engineer rather than that of the section foreman or "practical' roadmaster. For this reason, although its scope was somewhat limited, the book had a very extensive sale among engineers, but it has long been out of print. The steady and increasing demand from engineers for a technical book on track and maintenance of way led to the publication of the first edition of "Railway Track and Track Work" in 1897. The author had had this in preparation for some years previously, with the design of making a comprehensive book specially adapted for engineers, who are now entering more largely than ever before into the work and responsibilities of the maintenance of way department. It was published in the autumn of 1897. Within a few months the greater part of the edition was sold, and it was practically exhausted by the summer of 1900.

The continued demand for this book, not only from engineers but from the engineering schools, many of which have adopted it as a text book, has now been met by the preparation of this second edition, which has been entirely set up in new type and almost entirely rewritten. Since 1897, many changes and improvements have been made in materials and methods, while

new standards have been adopted with the general progress made in this department, and these various improvements are represented in the revision. Not only has the book been thoroughly revised, but many new illustrations have been made, and additional chapters have been added dealing with signals and interlocking and street railway track. As to the latter, it may be noted that street and country electric railways now offer such a wide and new field for engineers, that it was felt the book would not be complete without some mention of this branch of the subject. The tables of standard track construction in the appendix are also entirely new, having been prepared during the present year.

A special feature of the book is that it includes not only the general principles underlying track work, and the systems of practice which are everywhere applicable, but also includes numerous individual details of material, appliances and work, and methods of practice, which vary on different railways and in different sections of the country. It is believed that mere general statements as to methods of work and construction leave very much to be desired both by the beginner or student and by the engineer in charge of maintenance of way work. It has been the author's special aim therefore to present drawings and details of materials and methods, representing varied and actual practice, and to show their good and bad features, as well as the reasons for their use. This particular characteristic of the style of treatment adopted has met with very considerable commendation, showing that it meets a definite need. The scope of the book is large, as may be seen by a glance at the table of contents, and the various subjects included are treated not merely in a descriptive but also in a critical manner.

It would be impracticable to mention each and every engineer, railway officer and manufacturer of railway material who has furnished information to be made use of in this book, but the author takes the present opportunity to extend thanks for all information furnished, and for all the criticisms, corrections and commendations which have been sent to him.

E. E. RUSSELL TRATMAN.

Chicago, October, 1900.

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CHAPTER I.—INTRODUCTION.

The railway system of the United States now aggregates about 190,000 miles of railway, with 252,000 miles of track, the traffic over which amounts to about 862,000,000 train miles per year, while nearly 1% of the total population is directly employed in the railway service. The maintenance of 200,000 miles of main track, to keep it in proper condition to safely and efficiently carry the traffic, is a stupendous and never ending work, and one which affords great opportunities for the exercise of skill, judgment and executive ability in combining efficiency and economy in the conduct of the work.

The track upon which all the traffic has to be carried is one of the most important essentials of a railway. The importance of the track and track work in their relation to the operation of the railway, and the proportion of the total operating expenses which is represented by the expenditures on track maintenance, are not as generally recognized as they should be, even by railway officers. The idea held by many men not personally familiar with the service is that the track consists merely of two lines of rails laid upon timber ties, while the track work consists merely in attending to the spiking and bolting of rails and the occasional tamping of the ballast under the ties. A glance at the table of contents of this book will give a better idea of the variety of items included in track equipment, and of the variety of work required to be done in keeping the track in proper condition for the traffic. In addition to this, however, account must be taken of the care and forethought involved in devising the most economical construction, and the best and most economical methods of conducting the work under the various conditions of construction and operation which exist on different railways. In too many cases, also, it is taken for granted that any common laborer can be properly employed on track work, although it is almost universally recognized that a considerable amount of skilled labor is required to keep the motive power and rolling stock equipment in condition for safe and economical service. The opportunity is therefore taken in this introduction to call attention to the importance and responsibility of the engineer, the roadmaster, the section foreman and the section men, and to the relation which their work bears to the safe, efficient and economical operation of the railway.

There is an increasing recognition of the fact that the management of the track work and track forces should be in the hands of men of engineering training, and not in the hands of men who were simply somewhat above the grade of the ordinary section foreman. Many of the old road-

masters were (and are) of this latter type, and it is no discredit to them to say that they were rarely competent to understand the principles upon which track work is based or to deal with the higher problems in such work under modern conditions where speed of trains, a high grade of track construction, and a close economy in maintenance are involved. The Chief Engineer and his direct assistants have many other responsibilities besides those of the track, and very often these officials have no practical knowledge of track work, but have to rely to a large extent upon the roadmaster. The modern roadmaster, therefore, should combine engineering skill and knowledge with practical experience in the details of track work. This question is further discussed in the chapter on "Organization." There is still a strong tendency on the part of the financial and executive officers to ignore recommendations from and to reduce or disallow requisitions from the track department, owing in part, no doubt, to the old system of organization, under which it was generally understood that a roadmaster was not competent to consider matters involving the general management of the road. That this is the case appears to be proved by the fact that even on roads which are spending large sums for general improvements in realinement and reduction of curves, there is often a certain hesitation in regard to matters of track improvement. The engineers can show and the transportation officers can realize the direct economy in operation resulting from such expenditures for general improvement, but the questions of the relative advantages of heavier rails, better joints, treated ties, better ballast and improved appliances, are less liable to be fully presented or understood. One result of putting the maintenance of way into the hands of engineers, even as subordinates, will be that greater weight will be given to the opinions and recommendations of these men, whose qualifications will be understood by their immediate superiors and the higher officers.

One difficulty which the engineer and roadmaster and the superintendent and other technical officers have to meet is the very general confusion of the meaning of the terms "cheapness" and "economy" by non-technical officers. This applies more particularly in matters of detail. The officers may realize that large expenditures on improvements will result in economies in operating expenses, but are possessed by the idea that in buying supplies at a lower price than estimated or recommended, or in cutting down requisitions, they are practicing a commendable economy, whereas it is very probable that they are wasting money on inferior articles and hastening the time when larger expenditures will be required. It may be difficult, for instance, to convince them that very cheap supplies may be of such inferior quality as to ultimately involve more expense than supplies of better quality and higher price; or that, if a carefully prepared requisition of ties is cut in half, the distribution of the number where renewals are necessary may leave the track in little better condition than before. The technical officers, however, should have the courage of their convictions, based upon their personal knowledge, and should be prepared to press their arguments home in an endeavor to have the requirements of the case realized.

In regard to requisitions, the responsible officer should not let one pass to his superiors without being convinced that it is reasonable and fair,

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On the other hand, some railways in better circumstances apparently consider that, with the road once built, expenditures for the track should be permanently low. Therefore, while appropriating large sums for new locomotives and cars, handsome passenger trains, new stations, etc., and for freight and passenger competition expenses (which item might well be restricted), they are not willing to authorize liberal expenditures in track and roadway equipment. Many important roads, of course, are managed on a better system than this, but under the above conditions of service the officials of roads which cannot afford (or can but will not afford) needed improvements, have to do the best they can with such material and money as are available. In times of financial stringency, the above noted tendency to cut down expenses with a free hand is particularly evident. The too frequent result is a deterioration in the physical condition of the property, which (besides the loss of reputation to the railway) will very generally render extra expenses necessary to bring the road back to reasonably proper condition. It should be recognized as an established fact that the poorer the track the greater will be the expenses for maintenance and renewals, owing to the inability of the track to sustain the weights and shocks to which it is subjected. The importance of the maintenance department is perhaps most thoroughly understood by the officers of that department on a road where light track, fact trains, heavy traffic, rejected requisitions and frequent admonitions to keep the expenses down, together with a constant sense of responsibility in case of accident, make their positions anything but easy. Men in such positions are often largely instrumental in the successful operation of the road, but their work and responsibility are usually but little known outside of their own offices.

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A somewhat potent aid in a movement to improve the track is the introduction of higher speeds, since such conditions of traffic cause increased cutting of the ties, shifting of the ballast, and general disturbance of the line and surface of the track. The maintenance expenses are thus in-

masters were (and are) of this latter type, and it is no discredit to them to say that they were rarely competent to understand the principles upon which track work is based or to deal with the higher problems in such work under modern conditions where speed of trains, a high grade of track construction, and a close economy in maintenance are involved. The Chief Engineer and his direct assistants have many other responsibilities besides those of the track, and very often these officials have no practical knowledge of track work, but have to rely to a large extent upon the roadmaster. The modern roadmaster, therefore, should combine engineering skill and knowledge with practical experience in the details of track work. This question is further discussed in the chapter on "Organization." There is still a strong tendency on the part of the financial and executive officers to ignore recommendations from and to reduce or disallow requisitions from the track department, owing in part, no doubt, to the old system of organization, under which it was generally understood that a roadmaster was not competent to consider matters involving the general management of the road. That this is the case appears to be proved by the fact that even on roads which are spending large sums for general improvements in realinement and reduction of curves, there is often a certain hesitation in regard to matters of track improvement. The engineers can show and the transportation officers can realize the direct economy in operation resulting from such expenditures for general improvement, but the questions of the relative advantages of heavier rails, better joints, treated ties, better ballast and improved appliances, are less liable to be fully presented or understood. One result of putting the maintenance of way into the hands of engineers, even as subordinates, will be that greater weight will be given to the opinions and recommendations of these men, whose qualifications will be understood by their immediate superiors and the higher officers.

One difficulty which the engineer and roadmaster and the superintendent and other technical officers have to meet is the very general confusion of the meaning of the terms "cheapness" and "economy" by non-technical officers. This applies more particularly in matters of detail. The officers may realize that large expenditures on improvements will result in economies in operating expenses, but are possessed by the idea that in buying supplies at a lower price than estimated or recommended, or in cutting down requisitions, they are practicing a commendable economy, whereas it is very probable that they are wasting money on inferior articles and hastening the time when larger expenditures will be required. It may be difficult, for instance, to convince them that very cheap supplies may be of such inferior quality as to ultimately involve more expense than supplies of better quality and higher price; or that, if a carefully prepared requisition of ties is cut in half, the distribution of the number where renewals are necessary may leave the track in little better condition than before. The technical officers, however, should have the courage of their convictions, based upon their personal knowledge, and should be prepared to press their arguments home in an endeavor to have the requirements of the case realized.

In regard to requisitions, the responsible officer should not let one pass to his superiors without being convinced that it is reasonable and fair,

and that he can sustain it if it is called in question. He should at the same time be familiar with the financial conditions of the company, and regulate his requisitions accordingly, so that they may not be radically cut down by the executive officers, when he might have distributed the cut more judiciously and to better advantage. The aim of the officer in charge of track maintenance should be to do the best work possible with the amounts appropriated for his use. If the company is prosperous, he may turn his attention to important works or measures for the general improvement of the line, by which large expenditures will result in material economy in the future. If the company happens to be in straightened circumstances, it should be his particular aim to get the best possible results with the least possible expenditure, and to keep the track in the best possible condition. Many railways, owing to financial conditions, have to get on in the track and other departments with very limited means, and the officers of the departments have of necessity to carry out their work in a "hand-to-mouth" way that is by no means conducive to good or economical work. Under such conditions there is opportunity for the exercise of skill and judgment in distributing work and money to the best advantage, for such conditions are rarely an excuse for a thoroughly bad and neglected track.

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A somewhat potent aid in a movement to improve the track is the introduction of higher speeds, since such conditions of traffic cause increased cutting of the ties, shifting of the ballast, and general disturbance of the line and surface of the track. The maintenance expenses are thus in-

creased to a marked extent by a material increase of speed over a somewhat light track, and the traveling public will become aware of the fact that such a road is not a comfortable one to travel upon. Where a substantial track construction is introduced and maintained, the subsequent cost of maintenance is likely to decrease in spite of the higher speeds, the track being better able to resist the strains to which it is subjected. Under such conditions, the road would gain a reputation for comfortable service as well as high speed.

From what has been said, it will be readily believed that there is still in very many cases a lack of proper relation of the track to the traffic which it carries, and a deficiency in the maintenance. Train loads, wheel loads, speed and number of trains have steadily increased, while the track has not been improved in proportion to the extra strain and wear to which it is subjected, and the maintenance forces remain practically unchanged. On the other hand, there are many main lines having an excellent and substantial track construction, well maintained, and second to none in this or any other country, but these lines represent only a part of the total mileage of track carrying heavy traffic. Within the past few years there have been marked advances in track construction, notably in the use of heavier rails and of metal tie-plates, and in the introduction of improvements in frogs and switches. These tend towards a smaller expense for maintenance work and a greater degree of safety in the movement of trains. With all due credit and allowance for the progress that has been made, particularly within the past few years, it is certain that much remains to be done to bring the track into proper relation with the traffic conditions. Practical experience has conclusively shown the importance of substantial and smooth track in securing the maximum effective work of the motive power equipment, while at the same time such track will require less labor and expense for its maintenance. In view of the present tendency to the introduction of heavier engines, cars and trains, it may well be pointed out that resultant economy in transportation expenses may be offset by deterioration in track, with increase in expenses for maintenance of way, and increased liability to accident. The conditions vary, however, according to the nature of the road and the traffic. Thus, a light track which would be safe and economical on straight and level lines where the trains run easily, might be dangerous and expensive on a line with steep grades and sharp curves, over which the engines work heavily. So, also, a well-laid and well maintained track of comparatively light construction may give better service than a relatively heavier track less perfectly maintained and having low joints, worn ties and loose ballast. A low standard of maintenance may be expected where heavy traffic is imposed upon a light track with worn rails and ties, thin and inferior ballast and a general evidence of financial neglect. Yet such conditions are to be met with even on important lines. This is due largely to financial conditions (the various good and bad reasons for which have already been briefly considered), and to the fact that the other departments have in general received more attention than the roadway department. The attention of managers and higher officers should be called to the necessity for and the advantages of improved standards of track construction and maintenance. This subject was discussed in a paper on "The Relation of Track to Traffic on

American and Foreign Railways," read by the author before the New York Railway Club in 1896, in which paper details were given of actual conditions then existing.

An objection to American practice which has often been put forward by European engineers and railway men, is the comparatively light weight of rail used, but it must be remembered that the rail is only one part of the construction, and that it is not (as is often assumed) a girder resting on fixed supports. The whole track deflects under loads by the compression of the ballast and roadbed, independent of the deflection of the rails between the ties. Consequently, a 65-lb. or 70-lb. rail supported by 16 to 18 ties, may form a track smoother and more substantial than one with a 75-lb. or 80-lb. rail on 12 to 15 ties in the same length. It follows, also, that American track with 80 to 100-lb. rails, supported by 17 or 18 ties, will be more smooth and substantial than English track with rails of the same weight supported by only 10 or 12 ties. This is a point not unfrequently overlooked, and, in fact, some engineers have reasoned that by introducing heavier rails the number of ties can be reduced. This is by no means a safe proposition.

The proportion which the charges for maintenance of way and structures bear to the total operating expenses of American railways is usually high, as shown in Table No. 1, given below, and this is largely due to the fact that a majority of the roads have been built in the first place with regard to immediate cheapness and rapidity of construction rather than to ultimate economy in operation. The conditions under which the railways have been built (often in advance of the prospective traffic) have, on the whole, fully warranted the carrying out of the work on this principle. In too many cases, however, the mistake has been made of allowing the original style of construction to remain unaltered and unimproved long after it has been outgrown by the traffic. The result of this is that such roads have to sustain a heavy continual charge for maintenance. These conditions and their relation to operating conditions are now being given much greater consideration, and within the past few years many roads have spent enormous sums of money in general improvements, such as reducing grades and curves, improving the location, double tracking, improving yard and terminal arrangements, and replacing trestles and light structures with solid embankments and more permanent and substantial structures. In 1896, and again in 1900, the author made an extended investigation as to existing standards in track construction, and the results were published in "Engineering News," New York, June 25, 1896, and Aug. 30, 1900. Tables of these standards are given as an appendix to this book, and it must be understood that they represent the standard for main track only, regardless of lighter and less approved details of construction still in use, particularly on branches or lines of secondary importance. The construction shown by the tables, therefore, represents but a portion of the main track mileage of the several railways, though this portion is gradually increasing as renewals are carried on to meet the requirements of traffic.

As shown by the brief summary of statistics at the end of this chapter, the traffic on all the railways of the United States for the year ending

June 30, 1899, aggregated 862,258,714 train miles, and the operating expenses amounted to 65.24% of the gross earnings from operation. The largest item in the expenditures for operation is that of "conducting transportation," which includes all train and station service, and this item was 56.73% of the total, while the expenses for maintenance of way and structures amounted to 21.05%, and those of maintenance of equipment amounted to 17.62% of the total expenditures for operation. The expenditures for general improvements are not included in these figures. Analyzing the details of these figures, it is found that repairs to roadway represent about 10% of the entire operating expenses, while rail renewals and tie renewals represent 1.33% and 3%, respectively. A consideration of the fact that the maintenance work on track and structures absorbs over 21% of the operating expenses, and of the further fact that half of this is for ordinary roadway repairs (exclusive of rail and tie renewals), will show the relation which the maintenance department bears to the financial affairs of the railway company. Bearing this in mind, it becomes evident that greater importance should be attached to the proper organization and conduct of this department.

This general summary of the affairs of the railway system as a whole serves merely to indicate the average distribution of expenses, but it is of little use for application to individual cases. The advocates of reform in railway track construction, in the way of a more permanent character of work, have frequently called attention to the fact that, under the present system, the maintenance charges are extremely high. From official statements and annual reports Table No. 1 has been prepared, showing for sev-

TABLE NO. 1.—RAILWAY MAINTENANCE OF WAY EXPENSES.

			Cost of—					
			Maintenance of way.			Maintenance of way and structures.		
Railways.	No. miles.	Ratio of operating exp. to grs. earnings, per ct.	Per mile.	Per train-mile, cts.	Per cent. of op. exp., per ct.	Per mile.	Per train-mile, cts.	Per ct. of op. exp. per ct.
Me. Cen.	823	65 38	$696	17.6	17.4	$861	21.8	21.6
Fitchburg	825	69.00	1,340	11.3	11.5	2,036	17.7	17.7
N. Y., N. H. & Hart.	2,047	68.87	1,799	18.8	14.4	2,427	25.5	19.4
N. Y. Cen.	2,395	63.07	1,463	11.8	12.0	1,963	15.8	16.0
Erie	2,270	74.57	976	9.4	8.8	1,358	13.1	12.2
L. S. & Mich. So.	1,413	67.11	1,106	10.0	11.2	1,632	18.3	16.5
Mich. Cen.	1,658	72.25	787	....	13.0	1,190	....	19.4
Penn. R. R.*	2,190	68.00	...	....	....	3,264	....	18.0
Penn. Lines.	2,554	70.70	678	6.76	6.50	1,961	19.0	19.0
L. E. & West.	725	57.76	389	12.0	14.0	475	15.0	17.0
Chic. & N. W.	5.077	65.31	659	12.8	14.15	932	18.0	20.0
C., B. & Q.	7,419	64.84	591	14.7	16.5	852	21.13	23.8
C., M. & St. P.	6,154	62.55	582	14.5	15.0	829	20.07	21.3
C., R. I. & P.	3,619	66.17	642	15.9	18.2	898	22.3	25.4
Ill. Cen.	3,679	69.58	653	10.8	13.2	1,164	19.0	23.5
Iowa Cen.	513	70.53	...	....	....	938	26.0	32.0
M., Kan. & Tex.	2,200	67.00	...	....	....	601	15.6	15.6
Int. & Gt. Nor.	825	71.04	562	18.0	16.0	849	28.0	24.0
A., T. & S. F.	7,108	71.61	730	19.6	19.3	1,079	28.0	28.0
Nor. Pacific	4,635	47.40	546	24.4	21.7	765	34.2	28.7
Gt. Nor.	4,787	48.62	...	....	....	727	34.2	28.6
Can. Pacific	6,681	59.92	344	13.0	14.7	490	18.5	21.0
English Railways.								
Gt. East.	1,044	59.79	680	6.4	9.6	965	9.0	13.6
Gt. West.	2,509	62.21	735	8.2	12.0	1,355	15.4	22.4
Lan. & York	558	56.73	720	4.2	6.0	2,350	14.0	18.8
L. & N. W.	1,908	58.40	695	5.4	7.0	1,510	11.8	15.0
Midland	1,480	58.90	980	5.0	9.0	1,660	9.4	15.0

* Pennsylvania and New Jersey Divisions only.

eral railways the relation of the maintenance of way expenses to the mileage, train mileage and operating expenses. In many statistics of this kind the figures are simply given for "maintenance of way and structures," but the expenditures on structures vary within very wide limits, according to the character and number of structures, and these combined expenses cannot be reduced to any common or uniform basis for comparison. Under such conditions, the combined expenditure gives but little idea as to the comparative expenses for maintenance of way on different roads. For this table, therefore, the author has taken the expenditures for maintenance of way proper (including general work on roadway, rail and tie renewals, and ballasting) and shown their relation to the operating expenses and train mileage. In a few cases this cannot be done, the railways stating that they are unable to separate the expenditures on maintenance of way proper. Most of the figures are for the fiscal year ending in 1899, but some are for the year 1898. Most of them also include taxes in the operating expenses.

From the columns showing the cost of maintenance of way it will be seen that the expenses range from $546 to $1,463 per mile of road; from 6.76 to 24.4 cts. per revenue train mile, and from 6.50% to 21.7% of the operating expenses. The columns giving the cost of maintenance of way and structures show that these expenses range from $490 to $3,264 per mile of road, and from 15.6% to 32% of the operating expenses.

At the end of the table are given similar figures for five leading English railways, and these make an interesting comparison with the figures for American railways. The maintenance of way expenses of the former approximate to a low average of those of the latter when taken per mile of road, but are materially lower per train mile and form a considerably smaller percentage of the operating expenses. From this it will be seen that the English railways, with their almost universally substantial track construction, are operated more economically in regard to this branch of the expenditures. If, however, the varying character of track on the American roads could be classified, it would probably be seen that the maintenance of way expenses on first-class American track are about as low as, if not even lower than, those of the English roads. When we come to "maintenance of way and structures," the expenses per mile and the percentage of these expenses to the total operating expenses come closer to the results obtained on American roads, although the expenses per train mile are much lower. As to the percentage of operating expenses to gross earnings, there is not such a marked difference as is usually supposed. In fact, English railway men would probably be somewhat surprised to find that the percentage on representative American railways averages but little higher than that on English railways, instead of representing a great proportion of the earnings.

Throughout this book there are given numerous rules and instructions as to methods of work, but it must be distinctly understood that rules cannot be made universally applicable and should not therefore be followed blindly. Owing to varying conditions of track, traffic, topography, labor, etc., a method which may be the best practice in one case may be entirely unsuitable in another. Therefore every man must exercise his own judgment. He should not adopt a method simply because he finds it has been

used; nor should he assume that a method is wrong simply because it could not be applied to advantage on his own road or division. Engineers and roadmasters should comprehend the principles underlying their work. should be familiar with the general rules of practice outside their own particular sphere, and should take into consideration the actual conditions under which their work is to be done. Upon this basis they should devise or adopt such methods or materials as will give the best and most economical results under these governing conditions. It will be seen, therefore, that there is ample scope for a man to exert his skill and his executive ability in the conduct of the maintenance of way department.

In concluding this introductory chapter, the author gives the following summarized statistics for the railways of the United States, compiled from the report of the Interstate Commerce Commission for the year ending June 30, 1899:

AMERICAN RAILWAY STATISTICS. 1899.

Mileage.

Single track	189,295 miles.
Second track	11,547 "
Third track	1,047 "
Fourth track	790 "
Yard tracks and sidings	49,686 "
Total mileage operated	252,365 miles.

Employees.

	Number			
		Per 100 miles.		Total.
General administration		18		34,170
Maintenance of way and structures		153		287,163
Maintenance of equipment		96		180,749
Conducting transportation		223		417,508
Unclassified		5		9,334
Total		495		928,924
General officers, clerks, etc.		21		38,497
Station agents and men, operators and dispatchers		74		138,641
Enginemen, firemen and trainmen		95		178,851
Shopmen		94		176,815
Trackmen:				
Section foremen	17		31,690	
Section men	107		201,708	
Switchmen, flagmen and watchmen	26		48,686	
		150		282,084
Miscellaneous		61		114,036
Total (495 men per 100 miles)				928,924

Financial.

Total capital (stock and bonds)	$11,033,954,898
Total capital per mile of line	60,556

Traffic.

Passengers carried	523,176,508	Passenger train mileage	354,416,916
Passengers carried 1 mile	14,591,327,613	Freight train mileage	507,841,798
Freight carried, tons	959,763,583	Total train mileage	862,258,714
Freight carried 1 mile	123,667,257,153		

Earnings and Expenses.

	Per mile of line.	Total.
Gross earnings from operation	$7,005	$1,313,610,118
Operating expenses	4,570	856,968,999
Net income	875	164,154,813
Percentage of operating expenses to gross income	...	65.24%

Rev. per pass. per mile	1.925 cts.	Rev. per pass. train-mile	101.615 cts.
Rev. per ton per mile	0.724 "	Rev per freight train-mile	179.035 "
Revenue per train-mile, all trains			150.436 "
Average cost of running a train 1 mile			98.390 "

Total Expenditures for Operation.

	Per cent. of Op. exp.	Per cent. of Total exp.	Total.
Maintenance of way and structures	21.05	14.67	$180,410,806
Maintenance of equipment	17.62	12.27	150,919,249
Conducting transportation	56.73	39.53	486,159,607
General expenses	4.51	3.15	38,676,883
Unclassified	0.09	0.07	802,454
Total operating expenses	100.00	69.69	$856,968,999
Fixed charges	.....	30.31	372,792,458
Total expenditures	.....	100.00	$1,229,761,457

Expenditures for Maintenance of Way and Structures.

	Per cent. of Op. exp.	Per cent. of Total maint. exp.	Total.
Repairs of roadway	10.720	51.35	$87,307,140
Rail renewals	1.322	6.32	10,767,381
Tie renewals	2.901	13.88	23,623,325
Repairs and renewals of:			
Bridges and culverts	2.374	11.57	19,335,860
Fences, road crossings, signs & cattleguards	0.487	2.33	3,968,408
Buildings and fixtures	2.181	10.44	17,762,120
Docks and wharves	0.254	1.20	2,070,098
Telegraph	0.142	0.66	1,153,408
Stationery and printing	0.026	0.12	208,775
Other expenses	0.446	2.13	3,628,539
Total	20.853	100.00	$169,825,054

CHAPTER 2.—ROADBED CONSTRUCTION.

The general work of railway construction does not come within the scope of this book. It is assumed that the cuts and embankments have been completed to the level of the subgrade, and also that the bridges, culverts, tunnels and other works have been built. With the construction so far completed, the roadbed will conform to the required grades as laid down on the official profiles.

The width of roadbed (by which is meant the surface at subgrade) is from 26 to 32 ft. for double track and 14 to 18 ft. for single track on embankments; while in cuts it is from 28 to 33 ft. for double track and 18 to 22 ft. for single track. The width in cuts is exclusive of the ditches. The minimum widths should be 18 ft. in rock cuts, 20 ft. in earth cuts and 16 ft. on embankments. The surface at subgrade is almost invariably crowned at the middle so as to drain off water to the sides, and the roadbed may be formed in different ways to carry off the water reaching it through the ballast: (1) It may have one or more planes from each side to the center; (2) it may have a curved surface, or (3) it may have a flat center portion, with planes on each side extending to the ditch. In regions of ordinary rainfall the best plan is to give a slope, as it will throw off water better than a flat curve. The height of the crowning varies in different materials and districts, ranging from 3 to 8 ins. for single track, and from 4 to 10 ins. for double track. In a few cases a ditch is cut in the center of a double track roadbed, and in other cases the roadbed is inclined on curves to give the proper superelevation to the track, but this practice is very rare. The more solid and compact the surface of the roadbed is made before the ballast is applied, the better will be the drainage, and the more substantial will be the track itself. For this reason, the use of horse or

steam rollers in consolidating the roadbed would in many cases have a material influence in reducing maintenance expenses, especially for such work as surfacing and reballasting.

The drainage of the track is effected by the ballast and the crowning of the subgrade, together with side ditches in cuts to carry away the water from the ballast, roadbed and slopes. The drainage is one of the most important items in maintaining a good track economically, its importance increasing also in relation to the extent of the rainfall. Climatic conditions are, of course, to be carefully considered in designing the form of cross-section of roadbed and ditch. In dry regions with light soil, a steep slope and heavy ditching are not required, and under such conditions the slope of the roadbed is sometimes continued unbroken to the toe of the slope in cuts. With earth or other poor ballast in country with ordinary rainfall, it is better to have a ditch reaching well below the subgrade, so as to effectually drain the roadbed. Where the rainfall is only moderate the ditches should, nevertheless, be of ample capacity to carry off the storm water in occasional heavy rains. The ditches should be parallel with the track, and not made to wind around obstructing stumps or boulders. They must be graded to pass all water freely and to thoroughly drain the roadbed, so as to keep both roadbed and ballast dry and firm. The width should increase towards the ends, and if the standard width does not give sufficient capacity, the ditch should be widened on the outer side. The distance from the rail to the ditch varies according to the nature of the soil and the standard cross-section of roadbed. In ordinary material this distance is usually about 5 ft. 6 ins. to 7 ft., and the bottom of the ditch is 12 to 24 ins. wide and 6 to 12 ins. below the center of the roadbed.

In wet cuts the ditches may be lined with fine concrete, or in narrow wet cuts (especially where the earth slides or bulges) they may be lined with plank or old ties, with struts across the top. Subdrains of tile, brush, or wooden boxes may be laid as required, as noted in the chapter on "Drainage and Ditching." Where it is necessary to carry water from the ditch on one side of the track to the ditch on the other side, or from a center ditch to the side ditches (as on double track), wooden box drains are laid in the ballast. These box drains are usually about 10×12 ins. or 12×12 ins. inside, 12 to 16 ft. long, with the ends cut to conform to the slope of the ballast. They are made of 2-in. plank, and have four or six flat strips, $2 \times 6 \times 16$ ins., across the top. On the New York Central Ry., with double track in gravel ballast, these box drains are 6×6 ins., made of 2-in. plank, creosoted or treated with three coats of woodiline or other preservative. They are placed 400 to 500 ft. apart on tangents and 300 to 400 ft. apart on curves. They must be placed deep enough to permit tamping, and have an inclination of 1 in. per ft., or more, each way from the center line of the roadbed. The ditches may be carried under road crossings by cast-iron pipe, clay pipe or wooden box drains. The iron pipe is preferable. Wood soon rots and lets dirt fall in to clog the drain, and clay pipe is liable to be broken, as there is generally very little cover over it. The size of the pipe varies according to the amount of water to be carried, but is generally 6 to 10 ins.; while the box drains are about 8×10 ins., having plank sides and bottom, and a top of cross strips nailed close

together. Where the roadbed is wet and muddy in spots, the mud should be dug out and replaced with a filling of cinders or clean gravel.

New York Central Ry. (Fig. 1).—The double track roadbed is 26 ft. 8½ ins. wide, with a rise of 4 ins. The stone ballast consists of a 6-in. course, 25 ft. wide, of rough quarry spawls 4 to 6 ins. in size, closely laid, like the

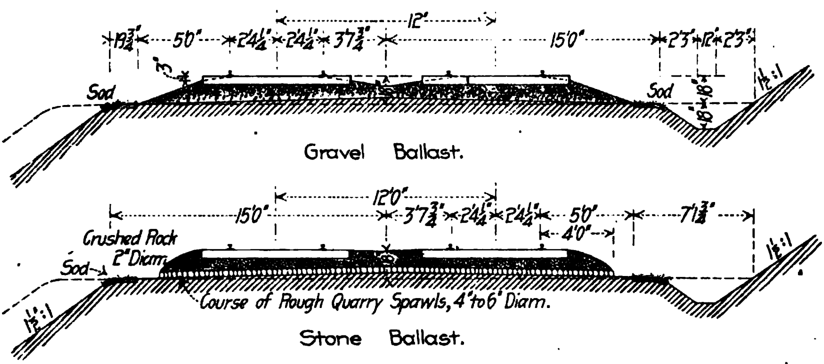


Fig. 1.—New York Central & Hudson River Ry.

foundation of a telford road. On this is a 12-in. course of 2-in. broken stone, filled in to the tops of the ties. A strip of sod is laid along the edge of the roadbed, as shown.

Pennsylvania Ry. (Fig. 2).—The width of roadbed is 19 ft. 2 ins. for single track, 31 ft. 4 ins. for double track, 43 ft. 6 ins. for three, and 55 ft. 8 ins. for four tracks. It has a slope of 1 in 48 from the center to the edge of the ballast, and then a berme 3 ft. 6 ins. wide, with a slope of 1 in 6 to the

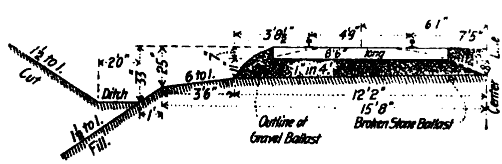


Fig. 2.—Pennsylvania Ry.

edge of the ditch or bank. The ballast is 8 ins. deep under the ties and for single track the width is 12 ft. 2 ins. wide over the toe. Gravel ballast is sloped off in a curve from the inside of the rail, while stone ballast is curved down from the top of the end of the tie, although the more general practice is to shoulder stone ballast out beyond the ties. Between the tracks gravel ballast is sloped down, while stone ballast is carried across level with the ties. In soft places, cinder ballast is used until the roadbed has settled and become consolidated. The standard section, shown in Fig. 2, has a well formed ditch, but no ditch is used on single track with light traffic. The quantity of ballast required per mile is as follows:

	Tracks.			
	One.	Two.	Three.	Four.
Stone, cu. yds.	2,315	5,300	8,500	12,260
Gravel, cu. yds.	1,900	4,075	6,950	10,185

New York, New Haven & Hartford Ry. (Fig. 3).—This road has a very flat roadbed, with no deep side ditches. The width is 30 ft. for double track and 54 ft. for four tracks, the latter being crowned only 3 ins. at the middle. Stone ballast is carried across level with the ties, shouldered out 12 ins. beyond their ends, and then finished with a slope of 1 to 1. Gravel ballast is

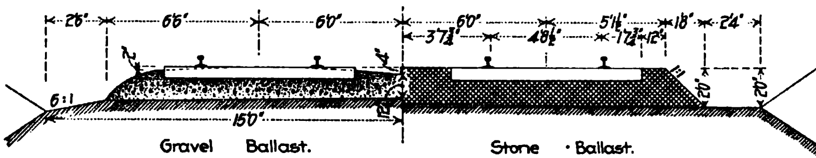


Fig. 3.—New York, New Haven & Hartford Ry.

level with the top of the ties for 18 ins. at the middle, and then slopes to 2 ins. below the top of the tie at the ends, as shown. Box drains are placed at intervals to carry the water from the middle drain to the side ditches. At the middle of the four-track roadbed the ballast is 11 ins. thick, 4 ins. below the tops of the ties.

Lake Shore & Michigan Southern Ry. (Fig. 4).—The width of roadbed is 32 ft. for double track, and in cuts the width between slopes is 47 ft. 6 ins. at the level of the subgrade. The gravel ballast is sloped down on each side, forming a drain between the tracks, while in cuts the gravel is spread

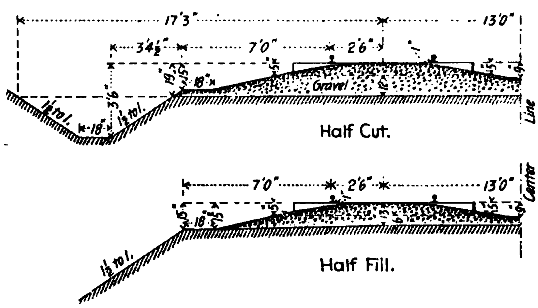


Fig. 4.—Lake Shore & Michigan Southern Ry.

on the 18-in. berme at the edge of the ditch. The depth of ballast under the ties is 12 ins. in cuts and 6 ins. on banks, and the quantity of gravel required per mile is as follows:

	Single track.	Double track.
In cuts, cu. yds.	3,749	6,917
On banks, cu. yds.	2,165	4,171

Baltimore & Ohio Ry. (Fig. 5).—The width of roadbed for single track is 19 ft. 1½ ins. in cuts and 17 ft. 1½ ins. on banks, while for double track the widths are 31 ft. 1¾ ins. and 29 ft. 1¾ ins., respectively. The standard section shows no regular ditch. Stone ballast is shouldered out 3 ins. beyond the ends of the ties, and sloped down between the tracks, while gravel

ballast is rounded off from inside the rail, touching the bottom of the tie. Cinder ballast (for side tracks) is shaped the same as broken stone. The depth of ballast under the ties is 12 ins., and on curves each track is laid

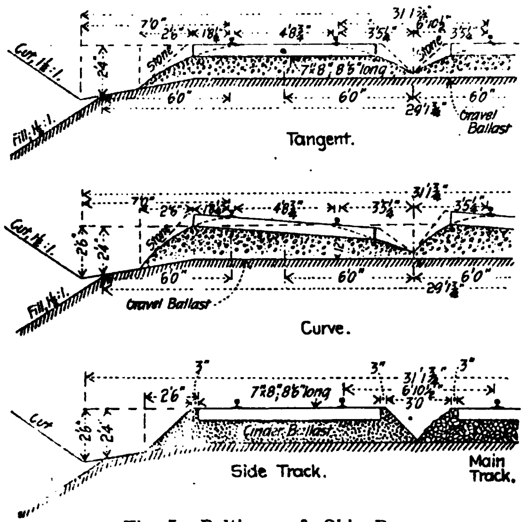


Fig. 5.—Baltimore & Ohio Ry.

with its rails in a separate plane, with 12 ins. of ballast under the lower rail.

Illinois Central Ry. (Fig. 6).—Where the track is ballasted with earth, the material is filled in to a depth of 4 ins. over the ties and then sloped down under the rails to the bottom of the ties, with a flatter slope ex-

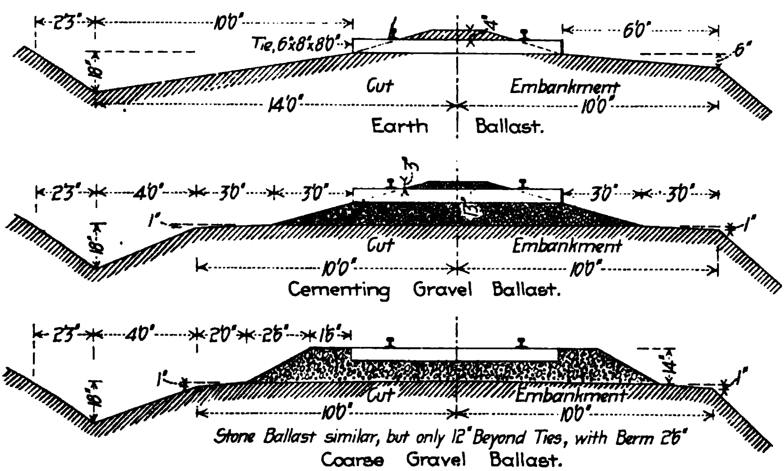


Fig. 6.—Illinois Central Ry.

tending thence 6 ft. to the toe of cut or 10 ft. to edge of bank, with a drop of 18 and 6 ins., respectively. Ballast of cementing gravel is formed

in much the same way, on a roadbed 20 ft. wide, being 13 ins. deep at the middle, where it extends 3 ins. above the ties. Ballast of coarse gravel is 14 ins. deep, level with the tops of the ties and shouldered out 18 ins. beyond their ends. Stone ballast is similarly formed, but is shouldered out

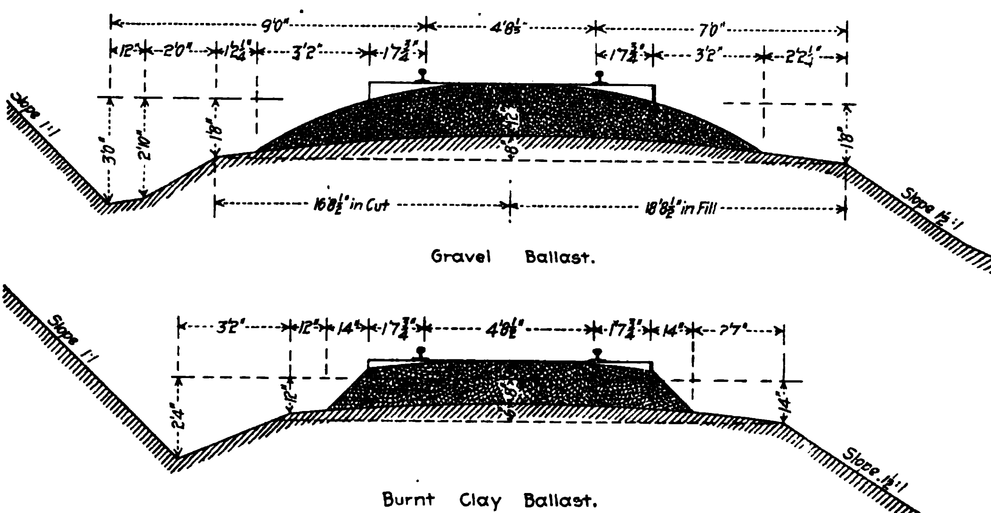


Fig. 7.—Chicago & Eastern Illinois Ry.

only 12 ins. It is 10 ft. wide on top, 15 ft. at the bottom and 14 ins. deep. A berme or bench 2 ft. 6 ins. wide, with a fall of 1 in., extends from the toe of the ballast to the edge of the 20-ft. roadbed.

Chicago & Eastern Illinois Ry. (Fig. 7).—The width of roadbed for double track is 29 ft. 8½ ins. in cuts and 31 ft. 8½ ins. on banks. For single track, the width is 16 ft. 8½ ins. and 18 ft. 8½ ins., respectively, with a crown of 6 ins. for burnt clay ballast and 8 ins. for gravel. The gravel is 12 ins. deep under the tie at the middle, and sloped in a uniform curve from the top of the toe at the center to the bottom at the ends, and a width of 14 ft. 4 ins. at the toe. There are about 1,800 cu. yds. of ballast per mile of single track. The burnt clay is level with the top of the tie between the rails, and then slopes to the middle of the tie at the ends, and thence to a bottom width of 10 ft. 4 ins. at the toe.

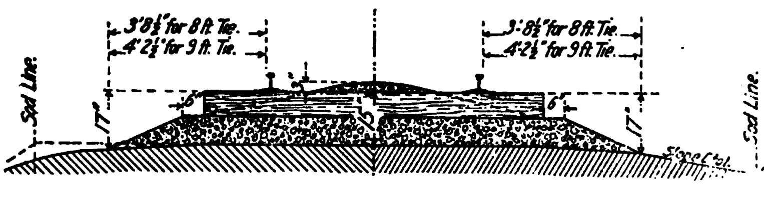


Fig. 8.—Southern Pacific Ry.

Southern Pacific Ry. (Fig. 8).—The single track roadbed is 16 ft. wide, increased to 18 ft. in cuts where rainfall is heavy, and 15 ft. is allowed for ex-

isting high banks. Stone ballast is shouldered out 6 ins. beyond the ties; it is 15 ins. deep (below top of tie) at the middle and 18 ins. at the toe, 4 ft. 2 ins. from the end of 8-ft. ties, beyond which the roadbed slopes 6 to 1 to the edge of the cut. Gravel ballast is shouldered out 6 ins. level with bottom of tie and filled in 3 ins. deep over the center of the tie, the depth being 15 ins. at the middle and 17 ins. at the toe. Earth is filled in 3 ins. over the

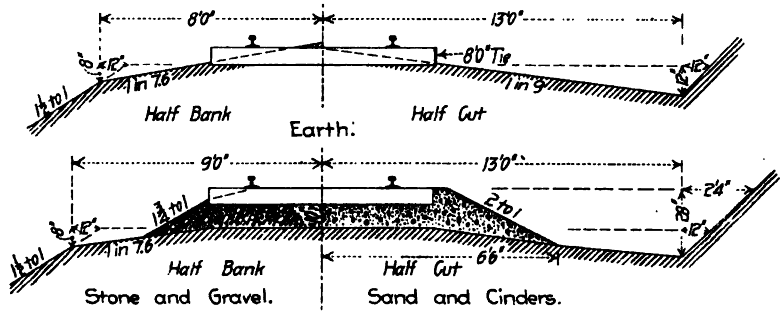


Fig. 9.—Atchison, Topeka & Santa Fe Ry.

ties and sloped to the bottom at the ends and thence to 16 ins. below top of tie at toe of cut or 14 ins. at edge of bank. In arid regions the sand is filled in level with tops of ties for 6 ins. beyond them and then sloped to 11 ins. below top at 42 ins. from end of 8 ft. tie, and 15 ins. at toe of cut or edge of bank. The standard cross sections call for rounding off the edges of banks to an even curve.

Atchison, Topeka & Santa Fe Ry. (Fig. 9).—The roadbed is flat for a width of 8 ft. and then slopes 1 to 7.6 on banks and 1 to 9 in cuts. The width for single track is 26 ft. in earth cuts, 21 ft. 6 ins. in rock cuts, and 18 ft. on banks, or 16 ft. 10 ins. on banks of branch lines. The ballast is 10 ins. deep under the ties. Stone and gravel are level with the tops of the ties between the rails, thence sloped to a few inches above the bottom

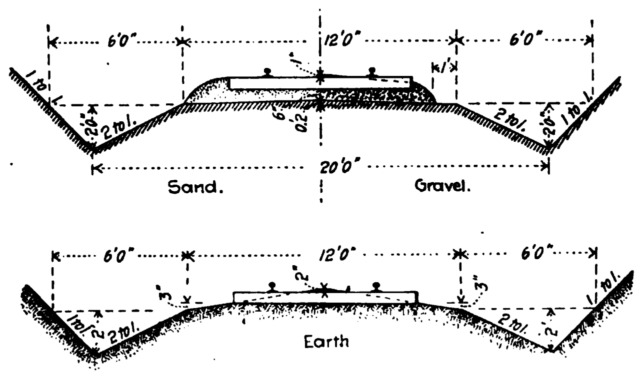


Fig. 10.—Minneapolis, St. Paul & Sault Ste. Marie Ry.

at the ends, and thence sloped 1¾ to 1 to the roadbed, the bottom width of ballast being 13 ft. Burnt clay, sand and cinder ballast are shouldered out 6 ins. and then sloped 2 to 1 to the roadbed. In filling trestles, the

banks are made 20 ft. wide at subgrade (or 18 ft. on branch lines) to allow for shrinkage.

Minneapolis, St. Paul & Sault Ste. Marie Ry. (Fig. 10).—The single track roadbed is 12 ft. wide, crowned 0.2 ft., and having deep ditches. Gravel ballast is filled in 1 in. over the ties, sloped to the middle at the ends and then rounded off to a width of 10 ft. at the toe. Sand ballast is filled in level with tops of ties, shouldered out 12 ins. and rounded to the edge of the ditch. This arrangement is not to be recommended, as the sand is likely to flow into the ditch. Earth ballast is filled in 2 ins. over the ties and sloped to bottom of tie at ends, and thence to the edge of the roadbed, 3 ins. below bottom of tie. In places where it was necessary to excavate to a depth of 1 to 3 ft. in sandy soil, the roadbed was made 28 ft. wide at subgrade, with ditches 8 ft. wide and 2½ ft. deep.

The standard sections adopted in 1899 by the Cleveland, Cincinnati, Chicago & St. Louis Ry. provide for a width of roadbed of 20 ft. for single track and 33 ft. for double track, with tracks 13 ft. c. to c. Stone and gravel ballast are 1 in. below top of tie at the ends and curved down to the roadbed at 6 ft. beyond and 25 ins. below base of rail. The ties are 7 ins. thick, with 12 ins. of ballast under them at the middle. On double track, the stone ballast is carried across level with the tops of the ties, while gravel ballast is sloped down between the tracks, leaving about 3 ins. of ballast at the lowest part.

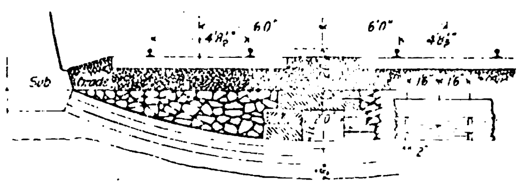


Fig. 11.—Baltimore Belt Line Tunnel; Baltimore & Ohio Ry.

The Lehigh Valley Ry., on its double track Buffalo line, has a roadbed 28 ft. wide in cuts and on banks, with V-shaped ditches 8 ins. deep, making the width 32 ft. over the ditches in cuts. The ballast is of stone or slag, 2 ft. deep, level with the tops of the ties and rounded out from their ends. The appearance of the track may be much improved by trimming the toe of the ballast to a line, and laying cinders between the toe and a strip of turf on the sod line.

Curves.—On the curves of most railways having two or more tracks, each track is inclined in a separate plane, all the lower rails being in the same horizontal plane. This plan is shown in the section of the Baltimore & Ohio Ry., Fig. 5. It is used on double and four track by the Pennsylvania Ry., but where crossovers occur, all the rails must be kept in the same inclined plane. This latter arrangement is also employed for ordinary use on curves on a few roads.

Tunnels.—The roadbed arrangement will depend upon the style of the floor, the amount of water to be dealt with, and the character of the ballast. In rock tunnels the floor is generally flat, sometimes with a trench drain down the middle, covered by flat stones to keep out the ballast, or else a

pipe drain is laid in the trench, and the ballast is filled in around it. With this arrangement the ballast is usually filled in level with the ties for the full width of the tunnel, but if there is no drain, the ballast may be sloped in the usual way to form side and center ditches. If the tunnel has an invert, there is usually an arched or box drain of brick or dry stone masonry, built upon the invert and covered by the ballast, although sometimes a pipe drain is laid in the ballast. The designs for brick and stone drains in the Baltimore (Howard St.) tunnel of the Baltimore & Ohio Ry. are shown in Fig. 11, while Fig. 12 shows the arrangement of floor,

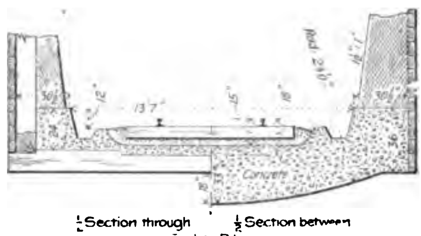


Fig. 12.—Tunnel; Everett & Monte Cristo Ry.

ballast and ditches adopted for the tunnels of the Everett & Monte Cristo Ry. A French engineer has proposed the formation of benches in the invert or floor masonry to carry longitudinal timbers for the rails, thus decreasing the height and cost of the tunnel, eliminating the ballast and ties, and reducing the work and expense of track maintenance in tunnels.

For rapid transit underground railways and circular iron-lined tunnels, special styles of construction are often used, although the Boston tunnel (for electric cars) has the ordinary track, with ties laid in stone ballast on a concrete invert with center drain. The New York underground railway will have the rails carried on a continuous bearing of wooden blocks, laid with the grain transverse to the rails, and fitted between channel-iron guard rails riveted to steel ties, these ties being embedded in concrete. The Central London electric underground railway has single-track circular tunnels, with a floor of concrete so shaped as to form benches or supports for two lines of longitudinal oak timbers 5 x 11 ins., with a broad drain between, as shown in Fig. 13. At intervals of 7 ft. 6 ins. there are oak

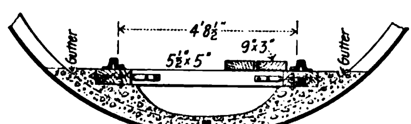


Fig. 13.—Tunnel of Central London Ry.

transoms, 5½ x 5 ins., fitted between the longitudinals. The rails are 60 ft. long, of bridge section, 7 ins. wide and 3½ ins. high, weighing 100 lbs. per yd. They are secured to the longitudinals by fang bolts 2 ft. 8 ins. apart, alternating on either side of the rail base. These bolts have square heads and are screwed down through heavy triangular nuts placed under the timbers, the nuts having points or fangs which bite into the wood,

and so prevent them from turning. The rails are laid with square joints, with a ribbed base plate, ½ x 7 x 20 ins., under the joint, the rib fitting the hollow of the rail. The end of each rail is held by four fang bolts, and has also two ⅞-in. holes for the rail bonds. Fig. 14 shows the unballasted floor construction of the St. Clair circular, iron-lined tunnel of the Grand Trunk Ry., in which the concrete floor is shaped to form a central drain with bearings for longitudinal timbers supporting the ties. A simpler construction is to lay the rails directly upon the longitudinals, as is done in many English tunnels. Wood or fibre-felt shims or plates will aid in reducing the noise. This construction, without ballast, is recommended in order to reduce corrosion of the rails and attachments, and to facilitate the work of repairs and renewals.

Bridges and Viaducts.—The roadway construction of steel bridges is discussed in the chapter on Bridge Floors. Masonry structures usually have the floor shaped to form drainage planes and ditches or gutters. The drains are either carried along the structure or lead to weeper holes or pipes forming outlets at the haunches of the arches, either at the spandrel walls or in the intrados of the arch.

Stations.—At large stations and terminals the ordinary form of construction is usually adopted, although special designs are occasionally used, as noted under the heading of "Longitudinals" in the chapter on

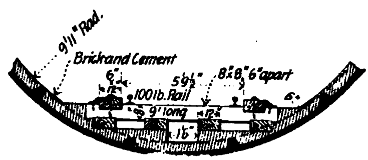


Fig. 14.—St. Clair Tunnel; Grand Trunk Ry.

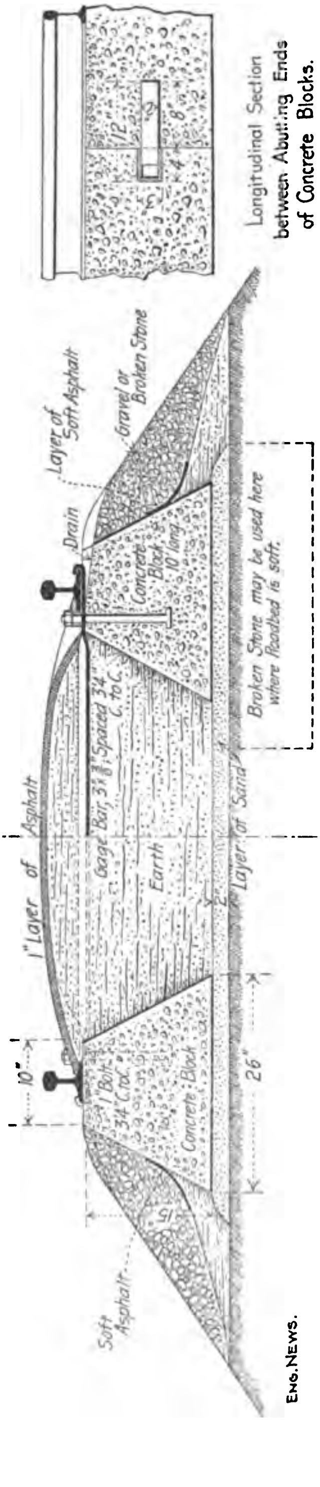
Ties and Tie Plates. At small stations, a filling of gravel or cinders is often used to form a level surface between the rails and tracks, coming up to the underside of rail head on the inside. Plank crosswalks may be provided to afford easy passage across the tracks. In some cases planks are laid along the rails, as at road crossings, to maintain the flangeway. The most general practice, probably, is to simply level off the ballast even with the tops of the ties to the edge of the station platform. The New York Central Ry. places on each side of each rail a plank 3 x 8 ins., with fillers on the ties of such thickness as to bring the planks nearly flush with the top of the rails. The outer planks are laid against the rail head. The inner ones are rabbeted on the edge with a square groove 1¾ ins. deep and 2¼ ins. wide, to form a flangeway. Between all the planks is a filling of cinders or coarse stone, covered with a 3-in. course of ¾-in. stone, and finished with a ⅜-in. top course of screenings wetted and rolled hard. This has a gentle slope from the station to the rail, and is level between the tracks and ties (See Station Platforms).

Yards.—There should be an ample depth of good ballast throughout the yards, with drains or water boxes leading to main drains, and these drains should be kept clean and open, and should be put in order just before winter. A wet, muddy yard is a source of inconvenience and discomfort to the yardmen, and is an evidence of neglect of proper maintenance.

Concrete Substructure.

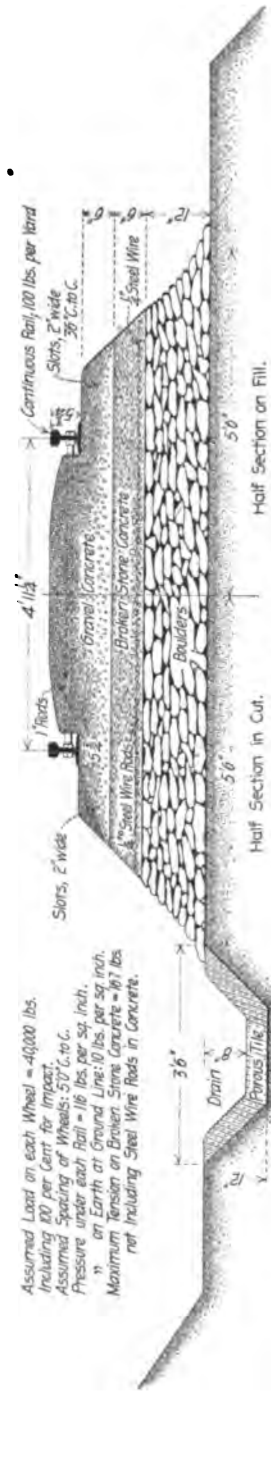
The idea is gaining foothold that eventually some more permanent character of track construction will have to be adopted in order to obtain greater durability and economy in maintenance than can be obtained with the present universal system of carrying the rails on wooden ties in loose ballast. To carry the rail and to distribute the load upon it over a large area of the roadbed, there are 15 to 18 separate supports in the form of cross ties, and a large proportion of the work of maintenance is that involved in the continual tamping of these supports in order to maintain a firm and uniform bearing for the rails. The ballast is at best an unstable foundation, and the effect of the weather and of the vibration due to traffic is to cause it to continually shift and settle, so that surfacing and raising are as continually required to keep the track in condition. Raising one tie disturbs its relations to those on each side, and every time a tie is renewed it disturbs the track for a certain distance on each side. For this reason better track can be obtained by renewing all the ties at once for a certain length of track, instead of making a few renewals in each rail length. This mutual disturbance of the ties and ballast is recognized as being one of the great and expensive difficulties in maintaining good track, and tie renewals alone represented 3% of the entire cost of railway operation in 1898. This system of construction has well served its purpose, and is admirable in its adaptability to roads having a wide range of traffic, while its first cost is decidedly low. The maintenance expenses which it involves, however, make some other system desirable to suit the present conditions of low interest charges and small margins of profit in railway affairs. An important question for consideration is whether some other system is available by which a sufficient saving can be made in annual operating expenses to pay the interest on the cost of making the change, with a fair profit besides.

The conditions above noted, accentuated by the great increase in wheel loads and train loads, have led to designs for a more permanent and (at first) more expensive style of track construction for lines of heavy traffic, though none have yet been actually tried. Most of these designs are based upon the use of concrete, or a combination of steel and concrete, as a substitute for ballast and ties, and three of these may be briefly referred to here. The first of these designs (Fig. 15) provides for concrete longitudinals, about 10 and 26 ins. wide on top and bottom, and 15 ins. deep, made in 10-ft. lengths and connected by dowels. These would be laid on a bed of sand on a well-rolled and consolidated roadbed, or on beds of broken stone laid in trenches where the roadbed is soft. Earth would be filled between and outside of the longitudinals, and either sprinkled with oil or covered with an asphalt composition to prevent water from getting through to the roadbed in any quantity. The rails would be held by some form of clamp and nut on bolts embedded in the concrete, with extra bolts at the joints, while tie bars would provide for adjustment of gage. The cost is estimated at about $5,000 per mile, exclusive of rails, with an additional sum of $1,000 per mile for tracklaying. The second design, Fig. 16, is for a foundation course of boulders (which are shown much too small in the drawing) covered with a 6-in. course of concrete made with



Cross Section between Gage Bars. Cross Section through Gage Bars.

Fig. 13.—Track with Concrete Longitudinals.



Half Section in Cut. Half Section on Fill.

Fig. 16.—Track with Concrete Base.

broken stone. On this again is a floor of gravel concrete, forming benches for the rails and filled in between the rails to cover the 1-in. tie-rods which form the rail fastenings. This style of fastening, however, certainly seems to be very inefficient and expensive. The cost is estimated at $6,000 per mile of single track, including laying, though the bed of boulders might probably be as well omitted. The third system, based on German ideas and an extremely massive construction, provides for 180-lb. rails on chairs composed of steel castings or pairs of Z-bars riveted at intervals of 2 ft. across longitudinals composed of special angles 8 x 6 ins., with ribs on the edges. Each longitudinal is composed of two of these angles, with the 6-in. legs vertical and 4 ins. apart, forming a top width of 20 ins. The rails are secured by clamps with ordinary or tap bolts, and angle tie bars serve to maintain the gage. The longitudinals are bedded in stone ballast, the designer considering that concrete is liable to disintegrate under vibration, while it does not admit of raising or surfacing the track. The cost of this construction, as shown in Fig. 17, including laying but exclusive of rails, is estimated at about $10,000 per mile.

In this connection reference may be made to the extensive and satisfactory use of heavy steel rails laid directly upon concrete longitudinals or floors in street railway track construction. The unsuccessful experiments made in the early days of railways with rails fastened direct to the solid rock floor of a cut are very often put forward as an argument to show the

Fig. 17.—Track with Steel Longitudinals.

necessity of providing elasticity in the track. This idea, however, has long ago been exploded. The more rigid the track, the better and easier the trains will ride, provided that it is rigid as a whole, with no independent movement or play between its parts. If the old rails could have been attached absolutely rigidly to the rock the results would have been different, but with light rails and primitive fastenings the rail was loose and was battered between the wheels and the rock foundation. It cannot safely be assumed that a continuous bearing will allow of lighter rails being used than with the cross-tie system. Unless the rail is stiff enough in itself, its tendency to deflect will impose severe strains upon the fastenings. The questions involved were discussed at some length in Engineering News, Jan. 5 and March 23, 1899, and the Railroad Gazette, 1899. One important objection which is urged against the concrete system is that banks, wet cuts, etc., settle almost continuously, but without uniformity, and the cross-tie system enables any part of the track construction to be repaired without interfering with traffic.

CHAPTER 3.—BALLAST.

Returning now to the existing system of track construction, the ballast is a most important item in securing a good track, with economy in maintenance and operation. Its purposes are (1) to distribute the load over the roadbed, (2) to form a support for the ties, (3) to provide efficient drainage under and around the ties, and (4) to allow of surfacing and raising track without disturbing the roadbed. It should not be laid until the roadbed is finally completed to grade and should not be used for raising banks to grade. The quantity of ballast should be liberal, with a depth of at least 12 ins. under the ties for track with heavy traffic, and the depth should be kept as uniform as possible. Where an old roadbed has been frequently reballasted, the ballast will be found to extend to a considerable depth, gradually becoming poorer from being worked into the soil, but this makes a good foundation for the ballast proper. The material should be carefully selected, as it may have a decided effect on locomotive and car maintenance, as well as on the traffic. A dusty ballast will cause greatly increased wear of the journals and motion, and on roads with extensive passenger traffic it is as important to avoid dust and dirt by the use of clean ballast, as it is to avoid smoke and cinders by the use of hard coal or coke for fuel for the locomotives. This fact is one of the principal reasons for the adoption within the past year or two of a system of sprinkling dusty ballast with oil, to prevent the clouds of dust commonly raised by the trains, as noted further on.

The best ballast is that which will best form a durable support to the ties, retain its solidity and position under the disturbing effects of weather and traffc, give good drainage, be free from dust, and make an easy riding track. Where water is retained under and around the ties, the ballast will soon deteriorate and be churned up, and bad track will result. The ends of the ties should be left entirely free (except in easy draining ballast, such as slag or broken stone), in order to allow water to escape quickly from under them, as in soft or earthy material the ties will churn the wet ballast into mud unless the ends are kept free. Gravel ballast, however, and especially where the gravel is coarse and clean, is sometimes filled a little above the bottom at the ends of the ties. In many cases, an expensive ballast hauled from a distance will in the end be more economical than cheaper and inferior material nearer at hand. This applies specially to roads with heavy traffic.

The materials most generally used are broken stone, furnace slag, burnt clay, gravel, sand, cinders and earth. Shells, chert, etc., are also used locally. Stone and slag will drain readily, but gravel, burnt clay, earth, etc., will retain water more or less (according to quality); and are liable to heave after frosty weather. The form of cross section given to the bed of ballast varies with the material, the climate, and the ideas of the engineers, but several forms have been shown in Figs. 1 to 10. The ties should not be covered with ballast as a rule, as it prevents inspection, and leads to rotting by keeping the ties damp, but in hot dry regions it may be permissible in order

to protect the ties from the sun. The standard depth of ballast under the ties rarely exceeds 12 ins., but there are many cases where it would be wise and economical to raise the track and give a greater depth of a better quality of ballast.

Broken Stone.—This is in general the best material for ballast as it meets all the requirements above noted, and can be worked in wet or dry, cold or hot weather alike. The best stone is hard and tough, which will not crush into dust, and which breaks into cube shaped pieces instead of thin flat pieces. Granite, trap and limestone are most used. The stone should be broken to a uniform size, and in general this has varied on different roads from 2 to 3 ins., but the present tendency is to use smaller stone. Stone broken to a ¾-in. size and screened has been used with good results; it is less noisy, wears the ties less, can be tamped more easily, and gives a better surface with less labor. Very coarse stone leaves too many voids, reducing the stability and increasing the difficulty of getting the track in good surface. In fact, it has sometimes been found desirable to apply a top dressing of screenings upon such ballast, making a close and dense mass which affords excellent support and is yet practically free from dirt. On the New York Central Ry., a bottom course of large rough stones is laid for a foundation (as in telford paving) and covered with the regular ballast of 2-in. stone. In general, the stone is bought from contractors, but many roads have their own crushing plants. The crusher should be placed above the track, and (if possible) below the quarry, so that the rock can be run direct to the hopper and the ballast delivered to the cars by chutes. Otherwise, elevators or conveyors will be required. For repair work, a rock crusher mounted on a flat car may be used, being hauled from place to place as required. In some cases the stone is broken by hand on the track, which is raised to surface by stones or blocking.

In cross section, the ballast is usually level with the tops of the ties, and extended or shouldered out beyond their ends, as the material drains readily and will not hold water under the ties, while the shoulder helps to hold the track in line. In some cases the ballast is rounded off from the ends of the ties, as in Fig. 2. It is better, and looks neater, to shoulder it out, especially with coarse stone, with which there is more tendency to lateral motion of the ties on curves. The slopes are sometimes hand faced for appearance, and the toe is very generally lined up, using a board against which a row of stones is laid by hand. On double track, the ballast is generally continued level across the whole width, with sometimes a row of large stones between the tracks to form a drain, these being covered with the regular ballast. Rarely it is sloped to form a center drain. Large stones may be laid between the tracks and behind the bank sills of trestles, etc., but must never be placed directly under the ties. Stone ballast should be handled with forks instead of shovels, so as to avoid putting dirt into the track, which will hinder drainage and afford a chance for weeds to grow. Old dirty stone ballast may often be made almost as good as new by digging it out and screening it. Near large cities this will often produce an almost incredible quantity of fine dirt, the accumulation of city dust and soot. From a maintenance point of view it may be noted that stone ballast on a poor road may involve greater expense for renewal (perhaps at a time when little money is available) than would be required for gravel. While the

first cost of stone ballast is considerably greater than that of sand, and the cost of maintenance is sometimes more, yet there is less liability of washouts, weeds do not grow, there is no dust, and the track holds its line and surface better.

Slag.—Furnace slag or cinder is extensively used on roads in the vicinity of blast furnaces and iron works. It is of varying quality, but the best is about as durable as broken stone and in other ways almost as good. Objections on the ground of causing corrosion of the rails are not sustained by experience. Coarse, spongy slag is apt to pulverize and deteriorate, both in tamping and under the effects of traffic, but the most satisfactory results are obtained from the finer glassy and hard slag. In fact, the Norfolk & Western Ry. uses this quality of slag in preference to stone. On the Chesapeake & Ohio Ry. it has been found to be satisfactory and economical, the depth being about 12 ins. below the ties. The bulk of this ballast is as small as ordinary gravel, obtained by pouring the slag down an incline of 30 to 40 ft., when it spreads out in thin layers and cools very rapidly. This gives it the appearance of broken china, instead of the porous sponge-like appearance of the large lumps of slag handled in the usual way. It is handled by steam shovels. Mr. Mordecai, Assistant Chief Engineer of the Erie Ry., states that furnace companies are generally glad to supply the material free on cars at the furnaces in order to get rid of it. It does not require much labor to break it up (from the large lumps) and the cost of putting it under the ties is about the same as with gravel or perhaps a little less. It should be handled by forks, to keep it free from dust and dirt. It should be at least 10 ins. deep under the ties. The tamping is done the same way as with stone, though Mr. Mordecai thinks that slag requires a little more tamping at the middle of the tie to keep the track in good condition for easy riding. It gives excellent results, keeps the track in good line and surface, and does not heave as much as gravel.

It was formerly broken to a 2-in. or 2½-in. size, but this has been found too large, and as now used it is either broken fine in a crusher, or discharged into water and so disintegrated as to be about the size of coarse sand. By either of these methods, however, the cost is about 30 cts. per cu. yd. On the Lehigh Valley Ry. the average size is from 1½ to 2½ or 3 ins., but stone is now being used in preference. The cross-section is usually formed similar to that for broken stone, and one advantage is that owing to the sharpness of its edges it checks people from walking on the track. It is extensively used in England, where it is run from the furnace onto a conveyor and suddenly cooled by water, which hardens it and breaks it up at the same time. In view of its low cost and its excellence as ballast, it might well be adopted by many roads now using inferior and dusty gravel on their main tracks. Where the traffic is heavy, the improved condition of track and the reduced cost of maintenance would probably warrant the expense for transportation of slag ballast from the furnaces.

Burnt Clay.—This has been used in England and other foreign countries for many years, and its use is extending in this country, mainly in the West. The most suitable material is brick clay, but almost any clay that has not too much sand may be used, as well as "gumbo" or clayey earth. The site for burning is cleared of top soil, and a row of cordwood, old ties, etc., about 3 ft. high, is laid the length of the kiln, 500 to 4,000 ft. This is

covered with a few inches of slack coal, or slack and lump mixed, upon which is thrown a layer of clay 9 to 12 ins. thick. The wood is then lighted at intervals, the openings being closed when the fire is started. As the burning proceeds, another layer of coal is placed and another layer of 6 to 9 ins. of clay, and these layers are repeated from time to time until the finished heap is about 20 ft. wide and 10 ft. high. One ton of slack coal will burn 3 to 5 cu. yds. of clay, and the material swells in burning, so that a cubic yard of clay will make nearly two cubic yards of ballast. The cost varies from 35 to 85 cts. per cu. yd., loaded on the cars. About 1,000 cu. yds. per day can be burned in a kiln 4,000 ft. long, about 50 men being employed. Unless the material is thoroughly burned it is liable to disintegrate and turn to dust and mud. The work is very generally done by contract, the company furnishing the land, sidetrack and coal. Partial estimates are given on kiln measurements, and the final estimate is made from car measurements when loaded out, so that worthless material is not paid for. The ballast is light (40 to 50 lbs. per cu. ft.) and must be used in liberal quantities to give good results and hold the track in line. The cross section is formed very similar to that for stone ballast, with the material well shouldered out and at least 12 ins. deep under the ties. This ballast is easily handled, drains well, does not heave, is free from weeds, is not dusty, and is in general satisfactory, requiring renewal in six to eight years. The cost on the Hannibal & St. Joseph Ry. is about $1.05 per cu. yd. of ballast in the track, distributed as follows, the price for the first item being variable:

Contract price for burning	38 cts.
Average cost of coal	21 "
Loading on cars	8 "
Distributing	9 "
Putting under ties	22 "
Interest and depreciation	4 "
Land	1 "
Miscellaneous expenses	2 "
Total cost per cu. yd.	$1.05

On the Chicago & Eastern Illinois Ry., in 1899, the cost was about 60 cts. per cu. yd. in the track, as compared with 50 cts. for gravel. The St. Louis, Keokuk & Northern Ry. used a black clayey soil or gumbo, and contracted for it burned in the pit. The railway laid the necessary tracks, furnished the old ties and slack coal, and loaded and hauled the ballast. The cost on the cars at the pit was estimated at 65 to 70 cts. per cu. yd., which is higher than usually estimated, but a number of small items were included which are sometimes overlooked. Burnt black wax soil on the Texas Midland Ry. is said to cost about $1 per cu. yd. in the track, and to have the advantage of being absorbent, so that in ordinary rainfalls most of the water is taken up by the ballast (which does not soften) and does not go through to the roadbed. Further particulars relating to burnt clay ballast are given in the writer's paper on "Improvements in Railway Track" (Transactions, American Society of Civil Engineers, March, 1890) and in "Engineering News," New York, Nov. 16, 1893.

Gravel.—This material is more used than any other, and is of very varying quality. It may be coarse and clean, or sandy and dusty, or loamy and cementing (when weeds will grow, drainage will be affected and the track will heave), or it may be full of large stones, in which case it will make an irregular and rough riding track. Cementing gravel should be avoided as far

as possible. The best gravel is clean and coarse, with stones of fairly uniform size, and as little sand as possible. Only very clean gravel will drain as well as stone. It is good economy to use plenty of gravel, giving at least 8 ins. (or better 10 ins.) under the ties, as this will enable a fairly good track to be maintained nearly all the year through without excessive work. It can be tamped by picks or bars, the latter being usually preferred, and is easily taken care of. Sandy gravel (like sand) may cause undue wear of tires, journals, etc. In fact, the substitution of slag for such gravel ballast on the Mobile and Montgomery Division of the Louisville & Nashville Ry., is said to have reduced the wear of engine tires from 1-16-in. per 9,000 miles to 1-16-in. per 16,000 miles. Screened gravel is used to some extent on the Pennsylvania Lines and the Lake Shore & Michigan Southern Ry., owing to the fact that the gravel as it comes from the pit contains 50 to 70% of sand, so that it is difficult to maintain the track in surface, the rains causing continual settlement by washing out the sand. The gravel is thrown into a hopper whence an elevator carries it to a revolving screen. In Europe, gravel is sometimes thoroughly washed and screened by machinery to free it entirely from earth and sand.

There are various forms of cross-section used, depending upon the quality of the material and the climatic conditions. With good, clean coarse gravel, particularly in warm dry regions, it is better to bring the ballast level with the top of the ties, and shoulder it out 6 to 12 ins. beyond them. With inferior, fine and loamy gravel, or where water and frost have to be considered, it is better to have the ballast level with the tops of the ties for only about 30 ins.; then sloping it to the middle or bottom of tie at the end, the latter being preferable with the poorer ballast. This will allow the water to drain off rapidly, the ballast being about 1 in. clear below the rail base. The gravel is sometimes filled in 2 or 3 ins. above the ties at the middle, but in wet country this keeps them damp and leads to rotting. In dry country, however, it may protect them from the sun, as well as from the engine cinders. The Houston & Texas Central Ry. fills in the gravel between the rails almost to the level of the underside of the rail heads, completely covering the ties. It is true that this causes a more rapid decay of the ties, but the gravel is of such quality that the track cannot be held without covering them either at the ends or the middle. The former practice causes even more rapid decay, owing to the washing out of the zinc solution, nearly all the ties being burnetized. On double track, gravel ballast is usually sloped to form a central drain, the bottom of which should be at least 6 ins. below the ties. Cross box drains in the ballast carry the water to the side ditches.

Cinders.—Engine cinders make a cheap and serviceable ballast which will last for some time under light traffic. Being porous, it drains well and does not hold moisture, but it is apt to make a dusty track for a time, until the rain and traffic have thoroughly compacted it. It is sometimes applied over a bed of stone or slag ballast upon which the ties rest. It is easily handled by the shovel, does not heave much under the action of frost, and prevents weeds from growing. A good layer of cinders will much facilitate maintenance with a wet roadbed and earth ballast in the spring or in wet weather, when the earth is too soft to support the loads and cannot be tamped. In

very bad cases the mud holes or wet spots may be dug out and filled with cinders. The cinders should not be laid on earth ballast when the frost is coming out of the ground, or this action will be checked, and it will be late in the season before it is thoroughly out. In cross section, this ballast is sometimes formed the same as for broken stone, the Atchison, Topeka & Santa Fe Ry. shouldering it out 6 ins. It is very generally used for side-tracks and yards. On a sidetrack it may either be sloped down to form a drain between that and the main track, as on the Baltimore & Ohio Ry., (Fig. 5), or it may be filled in level, as on the Erie Ry.

Sand.—This makes a fairly good ballast under light traffic, but unless it is very coarse it requires constant attention and considerable maintenance work, and renewal. The sand flows from under the ties as they move up and down under the traffic, is gradually drifted away by the wind, and is washed away by the rain. It is generally shaped the same as gravel, but if made level with the tops of the ties, and well shouldered out beyond them (as in Figs. 9 and 10), it will hold the track better, and there will be less flowing from under the ties. Clean sand will drain well enough if shaped thus. Owing to its lightness and instability it does not keep track well in alinement. It is liable to heave, makes a very dusty track, and is thus very hard on journals and machinery. In France and India, sand ballast is often covered with a layer of broken stone or broken brick to prevent strong winds from blowing it away. Special grasses or bushes may be used as wind breaks in sandy districts, as has been done extensively on the Siberian Railway and to some extent on the Old Colony Division of the New York, New Haven & Hartford Ry.

Earth.—Dirt, earth and mud are terms used for ballast composed of the natural soil along the line, which is the cheapest material to use but often the most troublesome and expensive to maintain. It is of variable quality, from sandy to clayey. Unless very sandy it cakes in hot weather, and if then disturbed by any work it becomes intolerably dusty. If well put up when dry, it will go through a wet season fairly well, but of course it cannot be handled when wet. It is liable to heave in the winter and to be washed by heavy rains. In continued wet seasons, or when the frost is coming out of the ground, it may become so soft as to make it impossible to keep the track in safe condition, the ties churning the saturated material into mud. In such a case, good results may be obtained by digging out the mud and filling in with cinders (as noted under Cinder Ballast), or sometimes sods, brush or coarse grass are packed under the ties. To keep the track in anything like good condition, thorough drainage is necessary. The ballast is usually filled in 1 to 4 ins. over the ties at the middle, and sloped sharply to the bottom at the ends, passing clear under the rail, and continuing on the same or a flatter slope to the edge of the ditch or bank. A flat slope will carry the water off more quickly than a curved cross section, and if the earth is at all above the bottom of the ties at the ends it is liable to form a pocket which will hold water and turn the ballast into mud. The roadbed should be thoroughly consolidated, so as to separate it from the earth ballast as far as possible, and thus assist drainage. On some lines in the Argentine Republic, which are ballasted with black loam, the surface is carefully formed and sloped in planes to drain rapidly to longitudinal and

transverse channels, while in some cases grass is allowed to grow upon and consolidate the surface.

Miscellaneous.—Oyster shells are used on some lines along the coast, and make an excellent ballast for light traffic, but do not hold the track under heavy traffic. Chert is a fine broken stone, resembling fine gravel, which is used in the South, mainly for branch lines. Chatts are the quartz rock tailings from lead mills, and resemble very coarse sand. Disintegrated granite, found largely in the Rocky Mountains, resembles a clean gravel except that the individual stones are sharp instead of round. It tamps well and makes a permanent and solid ballast.

Oiling Ballast.

The troubles incident to dusty ballast are numerous both in regard to wear of the journals and machinery, and to the discomforts of passengers. This is especially the case in summer, when the trains are almost enveloped in a cloud of dust or sand, and the passengers must either keep the windows closed or be half smothered. While the use of stone and other dustless ballast is being extended, it will be a long while before its use is universal. The dust nuisance is now being dealt with, however, on many roads by sprinkling the ballast with oil, on the system invented by Mr. J. H. Nichol, Assistant Engineer of the West Jersey & Seashore Ry., who first used it on that road in 1896. It not only provides for the comfort of passengers, but also reduces the chances of hot boxes, kills or tends to check the growth of weeds, and reduces the heaving action of frost. With very fine sand, the dust will still fly, but not to such an extent as before oiling. It is found, however, that the spikes more easily work loose in the oil-soaked ties. The oil used is a residuum of crude petroleum, having a high fire test, low gravity, and only a faint smell. The first application requires about 2,000 gallons per mile of single track, and about 500 to 600 gallons per mile per year will suffice to keep the ballast dustless after tie renewals, etc. It was thought that after a year or two no further sprinkling would be required, but this is found not to be the case. The sprinkling is done from a flat car fitted with a 2-in. pipe across the rails and a 2-in. swinging pipe on each side, these pipes having slots 1-16 x 3 ins. on the under side. With the side pipes swung out, a width of 14 to 20 ft. of roadbed can be sprinkled. The rails are protected by shields. The regulating valves and the swinging pipes are all controlled by levers or handles on the car. The sprinkler pipes are connected to a 4-in. main coupled up to a tank car in the rear, and this train is pushed by a locomotive at a speed of 3 to 4 miles an hour.

CHAPTER 4.—TIES AND TIE-PLATES.

The importance of the question of the source of supply for ties is shown by the fact that with an average of 2,500 ties per mile, the 250,000 miles of track in the United States represent 625,000,000 ties. The annual consumption is about 76,000,000 ties for renewals and 14,000,000 ties for new construction, or a total of nearly 100,000,000 ties, representing about 500,000,000 cu. ft. of forest grown material. This requires the annual culling of the best timber from about 1,000,000 acres, and the annual product of at least

50,000,000 acres in good condition, or about 10% of the present forest area of the United States, which is about 500,000,000 acres. These figures are necessarily but approximations, but they give some idea of the important relation which the ties bear to the railway system and to the timber resources of the country. Only the merest beginning has been made in regard to reforestation, but some advance has been made in protecting the existing resources. A few railways have done some tree planting, partly to make use of lands which are not wanted and are unproductive but on which taxes have to be paid. The Cleveland, Cincinnati, Chicago & St. Louis Ry. has set out several plantations of catalpa trees, which are quick growing and are available for ties and fence posts.

Wooden ties will undoubtedly continue to be generally used in this country for many years, but great economy in their use can be effected, to the benefit of the railways and of the country. The use of preservative processes to prevent decay, and of protective metal tie-plates to prevent wear and consequent rotting at the rail seats, results in an increased life of ties and reduced expense for renewals, and also makes a better track which requires less work for maintenance. The adoption of such preservative and protective methods is, therefore, strongly advocated, since ties of cheaper and (if untreated) inferior timbers, may thus be made even superior to ordinary ties of the better species of timber, and still cost about the same as, or even less than, the latter. The use of a rail fastening more efficient than the common spike would also increase the life of ties. There is no economy in using ties of poor quality simply because they are cheap. The cost of placing is the same, they give worse service and require more frequent attention, and the maintenance and renewals therefore cost more; while the frequent disturbance of track and ballast by renewals makes it almost impossible to maintain good track. Greater care in inspection for renewals, so as to ensure that the ties give their full effective life, will result in better track being maintained at reduced cost. An important economy resulting from the use of good ties and of methods for increasing their life, is the lessened disturbance of the track, thus permitting the ties to come to a solid bearing in the ballast and to remain upon it. One of the reasons for the economy in maintenance expenses with metal ties, is that when once well bedded they may be left undisturbed for many months, with very little work upon the ballast.

The principal timbers for ties are used in about the following proportions: Oak, 55% of all ties used; pine, 22%; cedar, 7%; chestnut, 5%; hemlock and tamarack, 4%; cypress, 3%; redwood, 2%; various woods, 2%. The geographical distribution of trees used for ties cannot be closely defined, but may be stated generally as follows:

New England States.—Chestnut, cedar, white and red oak, pitch pine, hemlock, tamarack, spruce.

Middle Atlantic States.—White oak, cedar, yellow pine, chestnut, tamarack, hemlock, cypress, cherry, locust.

South Atlantic States.—Pine, cypress, oak, chestnut.

North Central States.—Oak, cedar, hemlock, tamarack, locust, beech.

Gulf and Mississippi Valley States.—Oak, pine, cypress, walnut, locust.

Northwestern States.—Oak, elm, pine, tamarack, spruce, cedar.

Southwestern States.—Oak, pine, cedar, spruce, ash, cypress, catalpa.

Pacific States.—Oak, redwood, pine, and fir.

White oak is the best wood for ties, both for wear and durability, being very hard and slow to rot, and generally failing by decay rather than by

wear. Its average life is about 8 years under heavy traffic, though it sometimes lasts 10 to 12 years. On the Illinois Central Ry., the average life is 4 to 7½ years on lines south of the Ohio River (depending upon the height of land where timber was grown, the season when cut and the kind of ballast); 7 to 10 years in central and southern Illinois, and 9 to 12 years in northern Illinois and Iowa. Burr or rock oak and chestnut oak are next in value, lasting about 6 to 10 years, and are largely used for switch timbers. Pin oak is a medium quality. Black, red and yellow oak (which names are often used indiscriminately), are decidedly inferior species, lasting only about 4 or 5 years. Water oak lasts only about 4 years. Oak ties usually decay first in the part bedded in the ballast.

Pine is very largely used in its numerous varieties, of which yellow and white pine are the best, as, although they (especially the latter) are soft, they are slow to decay, and last from 6 to 8 years under light traffic or 10 years under heavy traffic. Southern pitch pine will last about 5 years in the south and 7 in the north. The checking of the pitch pine tie is one of its greatest defects, as the checks not only loosen the spikes, but cause openings for moisture to penetrate the interior of the tie. Short-leaf yellow pine from Georgia, Florida and South Carolina will last 4 to 5 years. This very much resembles the Baltic fir extensively used for ties in Europe, but the latter is harder, being grown in a colder country. The objections to tapped pine (or timber from which the turpentine has been drawn) on the ground of impaired strength and inferior quality, have not been sustained by experience. Some specifications exclude long-leaf pine grown north of South Carolina, but with little reason. Most of such timber having already been cut, it is doubtful if it can be obtained in quantity, and the chance of substitution is therefore greater, especially as in a lot of Southern pine few persons can distinguish one species from another. Yellow pine is very extensively used, but will decay in about 6 years, though it will resist wear for 10 or even 12 years. It is often preferred to oak for bridge ties, as it does not warp or twist so much. Spruce pine is also being used to a small extent, and is said to be more durable than Pennsylvania oak, while holding spikes better than chestnut.

Chestnut is equal to oak in point of durability, and from its resistance to decay is generally preferred to the latter for fence posts. White chestnut may last 10 years on tangents and under light traffic, but with heavy traffic it cuts under the rails. The ties have a tendency to split, and they usually decay first in the part above the ballast. Red and white cedar are good and durable. They last from 9 to 12 or even 15 years, but will cut under the rails unless protected by tie-plates. Cedar, like chestnut, does not hold the spikes well on curves. It fails by wear rather than by decay.

Hemlock is, as a rule, neither hard nor durable, and its life is very variable, from 4 to 8 years. It is extensively used on account of its cheapness, but is not good for first-class track, as it gets soft under the rails and at the spike holes. Spruce is about the same, lasting from 5 to 9 years. Tamarack or hackmatack (larch) is very commonly used, and will last from 5 to 10 years. Both tamarack and hemlock are being more generally used since the introduction of tie-plates. Black and red cypress is much used in the South, where there is an abundant supply. It is soft but durable, lasting 9 to 12 years if protected by metal tie-plates. Redwood is extremely

durable, but, being soft, it cuts badly under the rails, unless protected by tie-plates. Its ordinary life on the Southern Pacific Ry. is from 5 years upward, depending upon the traffic, but some specimens of black redwood (the best quality) last over 20 years if properly protected. It is only used in the Pacific states.

Black locust (which is a quick growing timber) is good, but scarce, and has a life of about 7 to 10 years. Honey locust is about the same. Black walnut and catalpa are used to a limited extent, and last about 8 years. The latter is another quick growing timber. All these are available only in small quantities. Beech is hard, but very poor unless treated, having a life of only 4 to 6 years. Elm and cherry are fairly hard, and will last 4 to 8 years, but cherry has a tendency to split in spiking. Maple, hickory, ash, birch, butternut and white beech are used to some extent, but are of little value, being by no means durable. They are rarely used except in first construction. Sassafras, mesquite and mulberry are also used to a small extent.

For inferior lines and sidetracks, second-class ties are used. The Allegheny Valley Ry, ranks red and black oak, pin oak, chestnut and cherry as second class. The Cleveland, Cincinnati, Chicago & St. Louis Ry. provides that such ties must not vary from the standard specifications by more than 2½ ins. in length, or 1 in. in thickness and width, and must not be so crooked that a line between the middle of the ends will pass outside the tie. Culls are inferior ties, not generally accepted under specifications.

The life of ties varies very considerably, and the apparent variation is exaggerated by the lax systems of inspection for renewal and the lack of system in keeping records of the ties. This point is discussed further on. The actual life varies in different sections of the country and on different railways, owing to the dissimilar qualities of timber of the same species grown in different parts, and to the influence of the varying conditions of climate, roadbed, and traffic. Ties in sidetracks should not be included in estimating or averaging the life of ties. Where ties are continuously obtained from one section of the country it is usually observed that the life of the ties is gradually becoming less as the timber resources become picked over. Specific information as to the life of various ties on individual roads is given in the table of standard track construction at the end of this book, and may be generally summarized as in Table No. 2, but the figures are necessarily approximations, for reasons already stated:

TABLE NO. 2.—LIFE OF TIES.

	Years.		Years.
Oak	5 to 10; av'g. 8	Spruce	6 to 8
White oak	6 to 12	Red spruce	6 " 9
Post oak	6 " 10	Fir (Douglas)	4 " 8
Rock or burr oak	8 " 10	Tamarack	4 " 8
Chestnut oak	8	Hemlock	5 " 8
Pine	5 " 8	Cypress	5 " 9
Yellow pine	4 " 11	Black cypress	10 " 12
Chestnut	5 " 10	Locust (honey)	8 " 10
Cedar	7 to 12 and 15	Catalpa	10 " 20
Sassafras	6 to 8	Walnut (black)	8 " 10
Hackberry	4	Cherry	6 " 8

Ties on curves generally fail by respiking and by cutting under the rail, so that they have to be taken out, as the gage cannot be maintained, although on tangents the ties would last perhaps two or three years more.

Ties usually last longer in good well-drained ballast, depending somewhat upon the form of cross-section. In some sandy soils, however, they decay even quicker than in clay soil, the former supplying the warmth, air and moisture necessary for fermentation, while the latter excludes air and warmth. On the Minneapolis, St. Paul & Sault Ste. Marie Ry., ties in sand ballast (level with the top of tie and shouldered out 12 ins. beyond the ends) give fully one year less service than in gravel ballast (sloped from 1 in. above the tie at the middle to 3 ins. below top of tie at the ends). They last best on the prairie lines, with loam ballast 2 ins. above the tie at the middle and sloped to the bottom at the ends. The traffic is lighter on the prairie lines. On the Missouri, Kansas & Texas Ry., ties of white, post and burr oak, cherry and sassafras have an average life of 6 to 7 years in earth and 8 years in stone or gravel ballast, under the usual traffic conditions of Western roads. The Allegheny Valley Ry. finds the average life of white oak ties in broken stone ballast, kept well drained and cleaned, to be about 9 years, under a traffic of 4,500,000 tons per year. The Central Ry. of New Jersey finds that first-class oak and yellow pine ties last about 8 years on main line tracks in broken stone or cinder ballast, and a little less in gravel. On the Union Pacific Ry. the average life of ties in different localities and under different conditions is as follows:

Kansas Division: White oak, 8 years. These ties are obtained from Arkansas, Indian Territory, etc., and last much longer than those from Wisconsin, Minnesota or Michigan.

Colorado Division: Natural soil ballast and moderate traffic; oak, 10 years; red spruce, 8 years; pine, 6 years.

Wyoming Division: Natural soil ballast; red or white cedar, with tie-plates, 15 or 16, and even 20 years; burnetized pine, 9 to 11 years; mountain pine, 7 years. The division is being ballasted, and better results are therefore expected for the future.

The idea that ties of old coarse timber are more liable to decay than those of young timber is not of general application. Young wood is the more apt to decay, owing to its larger proportion of albuminates, which form the food of the fungi. This timber is sometimes assumed to be more tough and fibrous, and therefore better fitted to resist decay, but as the sapwood of such ties becomes rotten in a few years, the size is reduced so that they are apt to be renewed without regard to the soundness of the heart. Sound, mature and well grown trees yield more durable timber than either very young or very old trees. In hard woods, trees of rapid growth (indicated by broad annual rings), due to favorable conditions of soil and light, yield the most durable timber, while second growth timber of proper age and quality should in general be equal to (or even preferable to) first growth. In coniferous woods, however, trees of slow growth (indicated by narrow rings) yield the better timber. The most durable timber for ties, therefore, is furnished by coniferous woods from comparatively poor soils, high altitudes and dense forest; and by hard woods from rich, deep, warm soils and open forest. In all cases within the same species, the heavier and denser wood is the most durable, and the heart wood is, of course, more durable than the sap wood. Winter is usually the best time for felling tie timber, especially if it is to be used without being seasoned, as it then contains less fermentable sap, and seasons more slowly and evenly before the temperature is warm enough to cause rot. The timber may rot with or without

fermentation, but usually without. Trees cut while in the leaf, as in the case of chestnut oak cut in May or June for tanbark, should be left for two or three months before being cut to size. In the South, pine is often cut during the summer, for which there is no apparent good reason. Timber cut when the sap is at rest is more durable than that cut when the sap is moving, mainly because fungus growth is less active in the former case. Full details respecting the structure and properties of tie timbers are given in a report on "Tie Timbers" by Mr. P. H. Dudley (Bulletin No. 1, Forestry Division, U. S. Department of Agriculture).

The importance of seasoning ties before use is not as generally recognized or practiced as it should be, although this practice is almost universally followed in Europe and accounts to some extent for the greater durability of the ties. Ties which are properly piled and left to season for a year (or at least six months) are far more durable than those put at once into the track. The ties should be barked and piled in rows of 8 to 12, spaced 6 ins. apart, and the rows separated by two ties at right angles to them. The pile should rest upon poles or blocking, as if laid directly upon the ground the fungus growth will soon attack the lower rows. The ties of the top row should be placed close together, and inclined so as to shed water. The piles should contain 50 to 100 ties each, and be at least 5 ft. apart to allow an inspector to examine and mark the ties. If piled near the track, they should be at least 7 ft. from the rail, and, if possible, on ground higher than the rails. Ties should not be piled in damp places in the woods where cut, but in dry, airy and shady places. More rapid seasoning may perhaps be effected by sinking the ties in running water for two weeks or more. On the Atchison, Topeka & Santa Fe Ry. it has been found that pine ties cut in summer and put directly in the track last 3 years; if cut in the winter they lasted 5 years when seasoned in air, and 5½ years when seasoned in water. The difference in this case, however, was too small to warrant a definite conclusion or the incurring of the extra trouble. Large timbers, as for switch ties, headblocks, bridge stringers, etc., should be seasoned under cover, as otherwise the sun may cause them to season irregularly and to become warped.

Hewed ties are very generally assumed to be superior to sawed ties, and this has led to a custom of insisting that ties must be cut from trees that will make but one tie each, or to insist that the cut shall make but one tie. Two reasons are given why sawed ties are apt to decay more rapidly: (1) They present increased end surfaces of the grain, as the cut cannot be kept parallel with the fibre (especially when the log is not quite straight); this exposes bastard faces on the sides, which are simply partial cross-sections; (2) The saw does not make a sharp smooth cut, but leaves a more or less woolly surface, which permits the accumulation of water and affords opportunity for fungus growth. The second objection may be overcome by the use of a planer saw, which cuts and planes the surface. Sawed ties are being more and more used, and if treated by preservative processes the above objections are eliminated. Opinions and experience vary as to their use. The Cleveland, Cincinnati, Chicago & St. Louis Ry. specifications formerly required sawed ties to be 9 ins. wide, and hewed ties 8 ins. wide, but the former are now accepted if 8 ins. wide and good in all respects. Mr. W. W. Rich, formerly Chief Engineer of the Minneapolis, St. Paul & Sault

Ste. Marie Ry., prefers ties made from round timber sawed on two sides, as experience indicates that they give longer service than hewed ties. This result was not expected, and is contrary to tradition. The objections to split ties are passing away, except as to the quick and deep season checking, which takes place in a split tie having the heart on one side. In Europe, S-shaped pieces of hoop iron are driven into the ends of checked ties to prevent the checks from widening. Warped, twisted and crooked ties should not be used, as they are liable to rock in the ballast. The ties should invariably be stripped of bark, or it will hold water in the ballast and against the tie. When the bark eventually becomes loose it makes a very unsightly track and interferes with proper tamping, while it allows the track to shift, the ties slipping out of the smooth bark instead of being held by the rough ballast.

Ties should be made from sound, thrifty, live or green timber, free from loose or rotten knots, wormholes, dry rot, wind shakes, splits or other imperfections which affect their strength or durability. They should have no sapwood on either face, and not more than 1 in. on the edges or corners. They should be hewed or sawed with the faces perfectly true and parallel, should be of the specified thickness, the faces out of wind, smooth and free from any inequality of surface, deep or bad score marks, or splinters, and should be not more than 3 ins. out of straight in any direction. They should be of uniform size, and those of the same kind should be kept together as far as possible, to ensure approximate uniformity in wear. The specifications should be carefully and intelligently prepared, and their requirements strictly enforced, inspectors being instructed to reject all ties which are not of the required quality or dimensions, and being sustained in this by their superior officers. Accepted ties should be distinctly marked with paint by the inspectors.

There are two principal elements governing the life of a tie: (1) Its resistance to decay; (2) its resistance to the wear resulting from the cutting and abrading action of the rail. The direct compression under the rail is too slight to enter into consideration. Ties are injured, destroyed or rendered unserviceable by three principal causes: (1) Mechanical disintegration of fiber and the abrasion of fiber under the rails caused by the slight motion of the rail on the tie; (2) injury by spiking and respiking; (3) general natural decay of the wood, induced by fungus growths. Under ordinary and average conditions on American railways, ties have to be renewed more on account of the cutting and abrasion (and consequent local decay) under the rails than on account of natural decay. Mr. Katte, formerly Chief Engineer of the New York Central Ry., estimated that 20% of the ties taken out were removed on account of this class of injury, from 10 to 15% being reported as "crushed or broomed," and from 4 to 10% as "cut out" by respiking. This cutting and abrasion may be largely reduced by adopting improved rail fastenings to hold the rails and ties more firmly together. It may be almost entirely eliminated by the use of suitable metal tie-plates, which thus effect a decided economy in making ties of the softer and cheaper woods equally as serviceable as the harder and more expensive. Ties will wear out more quickly on curves on account of the lateral strain on the rails forcing the spikes back, enlarging the spike holes and reducing the frictional hold of the spike in the tie. They also wear out more quickly

on heavy grades where the engines use sand. In both these cases metal tie-plates will aid materially to prevent the cutting and maintain the track in good condition.

The natural decay of the tie as a whole depends largely upon the wood, ballast, climate, etc. It usually begins at the ends and is much hastened by season checking, though this may be prevented by painting the ends with a resin or cheap paint or composition, so as to cause a slower exchange of moisture. The resin thrown away at the Southern turpentine distilleries might be made available for this purpose. Boring the holes for the spikes, as noted in the chapter on Rail Fastenings, would prevent much of the checking, and if the size of the hole is proportioned to that of the spike it should increase the holding power. Ties should never be moved by sticking picks into them, as such practice forms places where decay may start. In rare cases the ties have the rail seats "spotted" or leveled off by machine. This is very generally done in Europe, the rail seat being inclined so as to be parallel with the conical face of the wheel tires. The wheels, however, have an inclination of 1 in 20, while in this country it is only 1 in 38. The true economical reform in railway ties, before metal track is considered, will provide for preservative treatment by impregnation and the use of metal tie-plates.

Smaller ties usually resist decay better than large ones, and with tie-plates to prevent cutting, such ties may advisedly be used. A large number of ties of medium width is better than a smaller number of wider ties in making an easy riding track. The thickness varies from 6 to 8 ins., but should never be less than 6 ins., or the spike may cause a crack in the bottom, besides which the deeper tie has greater stiffness to resist transverse bending. The width is from 6 to 10 (or even 12) ins., but 8 ins. is a very good width for supporting the rail and bedding in the ballast. Where there is much difference, the wider ones may be used for joint and shoulder ties. Very wide ties are awkward to handle and tamp, require too much digging in renewals, and are liable to rock in the ballast. The necessity of uniform size has already been referred to, to form an easy riding track and to reduce the disturbance of the ballast bed in renewals. If the thickness and depth are not uniform, then in renewals the tie-beds will have to be dug out or filled in, thus disturbing the stability of the track. The length ranges from 8 to 10 ft., the latter being used (mainly in swampy districts) on some parts of the Southern Pacific Ry., Louisville & Nashville Ry., etc., while the Canadian Pacific Ry. used ties 9 ft. long on its line between Montreal and Smith's Falls, on account of the heavy traffic. The usual lengths are 8 ft. and 8 ft. 6 ins., and for ordinary track it is doubtful if an increase beyond the latter gives much effective bearing or is of much real use. The length should be uniform, for it is easy to cut the ties to the right length, and this will be done if the inspector insists upon it. Where it is not uniform, the ends should be lined on one side of the track. To facilitate this, a notch should be cut in the handle of a spike maul at the proper distance (varying with the width of rail base and length of tie), and in placing the tie, the end of the handle is placed against the outer edge of the rail and the tie pushed in till its end is in line with the notch. Square sawed timbers of varying length are used at turnouts, and square sawed ties on bridges and trestles.

The standard sizes of ties on a few roads are given in Table No. 3, to show the variation, but a longer list will be found in the tables of standard track construction at the end of the book.

TABLE NO. 3.—SIZE OF TIES.

Railways.	Thickness, ins.	Width, ins.	Length, ft.	Railways.	Thickness, ins.	Width, ins.	Length, ft.
Baltimore & Ohio..	7	8	8½	Fitchburg	6	6	8
B., Roch. & Pitts.	7	7	9½	N. Y. Central.....	6	9	8
Chesapeake & Ohio	7	7	8½	Pennsylvania	7	10	8½
Chic. & N. W.....	6	8	8	Plant Lines	7	9	9
C., C., C. & St. L..	7	8	8	So. Pac. (cypress).	7	10	9
D., Lack. & West.	7	9	8½	Union Pac. (pine).	8	8	8

The spacing of ties varies from 2,240 to 3,200 per mile, or from 14 to 18 per 30-ft. rail, but there should be not less than 16 ties per rail on main track. The number of ties should not be reduced as heavier rails are introduced, for it must be remembered that the track as a whole has a certain deflection (in addition to the deflection of the rails), so that reducing the number of bearing points only serves to increase this liability to deflection. This point is often overlooked in European practice. The deflection for a given rail and load varies practically as the cube of the tie spacing. Therefore, if we take 1 as the deflection between ties 20 ins. c. to c., the deflection for ties spaced 24, 30 and 36 ins. c. to c. will be 1.73, 3.38 and 5.83, respectively.

The Pennsylvania Ry. uses 14 to 16 ties per 30-ft. rail on main track, and 12 for sidings and yards; Boston & Albany Ry., 15; Southern Ry., 16; Fitchburg Ry., 16 on tangents and 17 to 18 on curves; Northern Pacific Ry., 17; Illinois Central Ry., 18 on main track (under 85-lb. rails) and 15 on side track; Denver & Rio Grande Ry., 19. On the San Francisco extension of the Atchison, Topeka & Sante Fe Ry., there are 17 ties per rail on tangents, 18 on curves up to 3°, and 19 on curves over 3°. The New York Central Ry. uses 18 and 20 ties to rails 30 and 33 ft. long, laid with three-tie broken joints; the three joint ties are 14½ ins. c. to c., and the others 21½ ins. for 30-ft. and 21⅛ ins. for 33-ft. rails. The joint and shoulder ties should be somewhat closer together than the intermediates, so as to give increased bearing towards the rail ends, where the tendency to deflection is greater. The intermediate ties may be 16 to 24 ins. apart in the clear, and joint ties 8 to 16 ins. apart, though the Pennsylvania Ry. considers that a less spacing than 10 ins. does not allow of proper tamping. With three-tie joints, however, the clear spacing may be 6 to 8 ins., and on bridge floors the spacing should not exceed 4 ins. The Southern Pacific Ry. spaces the ties 14 ins. c. to c. at joints, and 20 to 24 ins. intermediate, according to the number per rail. Some roads having light rails and heavy traffic space the ties by the width of a shovel, without regard to any fixed number of ties per rail, it being considered that on such tracks nearly 50% of the length of the rail should be supported. A few roads also specify a certain length of tie-bearing per rail, the Duluth & Iron Range Ry. specifying 130 ins., but neither of these two methods are good practice for main track. The number of ties per mile of single track for various uniform spacing is given in Table No. 4, but many roads lay one or more extra ties per rail on curves.

TABLE NO. 4.—NUMBER OF TIES PER MILE.

No. per 30-ft. rail.	Spacing, c. to c., ins.	No. per mile.	No. per 30-ft. rail.	Spacing, c. to c., ins.	No. per mile.
10	36	1,760	15	24	2,640
11*	33	1,920	16	22.5	2,816
12	30	2,112	17	21.2	2,992
13*	28	2,270	18	20	3,168
14	25.7	2,464	19	19	3,344

*Approximate.

Longitudinals.—Longitudinal timbers instead of cross-ties are used in general track construction in Europe to a very limited extent, but are quite generally used on bridges and in tunnels. They are used on the Long Bridge at Washington, which carries the Pennsylvania Ry. over the Potomac River, and they were used in the old tubular Victoria Bridge of the Grand Trunk Ry. over the St. Lawrence River at Montreal. This latter bridge has now been rebuilt, with truss spans and the ordinary style of floor. Longitudinals are also used to some extent in large stations. In the Louisville & Nashville Ry. station at Louisville the 80-lb. rails are laid upon continuous iron plates on longitudinals 12 x 12 ins., supported by cross-ties. The spikes pass through the plates. In the Broad St. station of the Pennsylvania Ry., at Philadelphia, the rails rest upon wooden blocks 2 ins. thick (19 blocks to a rail length) placed on longitudinal timbers, there being no blocks under the joints. The timbers rest upon 11 ties to each rail length, there being a tie under each joint, and the stone ballast is level with the tops of these ties.

Tie Renewals.

The tie renewals are too frequently considered by executive officers as a comparatively unimportant item in the expense account of maintenance of way, owing to their failure to appreciate the expenses involved in the renewals, which, of course, should include the cost of all labor for removing the old and putting in the new ties. As a consequence of this, tie expenses are continually increasing, while much of the general maintenance expense for labor can be charged to the deterioration of track due to the softening of ties from incipient decay, and to the mere frequent renewals of ties. The cost of putting a tie in the track is estimated at 20 to 50% of its first cost, while on the Erie Ry. the cost of labor has been estimated at 9 to 14½ cts. per tie. The renewals average about 250 to 350 ties per mile per year for main tracks, and 200 to 250 for side tracks, but these figures may be considerably reduced by the use of preservative processes and metal tie-plates. The average number of tie renewals per year per mile of main track during 15 years on some leading railways has been as follows: Chicago, Milwaukee & St. Paul Ry., 243; Pennsylvania Lines, 245; Chicago & Northwestern Ry., 280; Illinois Central Ry., 300; Louisville & Nashville Ry., 360. It will readily be seen that a road which has to renew its ties in 6 years is at a disadvantage when compared with one whose ties last 12 years. The former must not only figure into its expense account almost double the cost for material and track labor, but during the interval it cannot have as good a track, owing to the additional amount of disturbance for renewals.

The average cost of tie renewals is now considerably in excess of that of rail renewals, and shows a tendency to increase, for the following reasons: (1) Increase in price of ties, owing to the increased value of timber as the

supply is diminished, and to the increased haul as the sources of supply become more distant; (2) the use of the best timber for other purposes, so that the poorer qualities must be cut for ties, giving consequently inferior service; (3) less rigid inspection and the acceptance of inferior ties; (4) increased tendency to cutting and decay under the rails, due to increased wheel loads and traffic; (5) spike killing, caused by regaging, redriving loosened spikes, etc., which also is due to increased wheel loads and traffic.

Ties have a most irregular life, even when cut at the same time from the same locality, and as the annual renewals average 250 to 350 per mile, there is probably hardly a rail length of main track which has not at least one tie renewed each year. The cost involved includes the first cost of the new tie, the labor cost of renewal, and probably the cost of some new spikes. The old ties are usually absolutely valueless, so that there is no credit for "value of old material," and if any of the old spikes are bent or broken in pulling, they are as likely to be thrown away as to be sent to the scrap pile, thus involving another incidental expense. It is practically impossible to get the new tie at once as well and firmly bedded as the old one, which has probably been cut into by the rail so as to reduce its thickness. When the new tie is in place, therefore, it may be either tight (raising the rail slightly above its normal surface) or loose (allowing the rail to deflect before the tie gives it proper support). If we consider such conditions as occurring once in each rail length of track, it will be seen that a certain increase in wear of rails and wheels, and in the motion of cars, must result. These effects will continue until the traffic (pounding from above) and the section men (tamping from below) have restored the normal surface of the track, as far as may be in view of the increased wear which has been sustained. By the use of metal tie-plates; and treated ties of longer and more uniform life, all this expense and work may be required only at long intervals, and individual renewals will be much less frequent. Under such conditions this would be a saving in operating expenses, distributed partly in the roadway department and partly in the transportation department.

Close attention should be paid to requisitions for ties. If they are granted too liberally and without question, there will be a tendency among the foremen to take out ties before they have given their proper service. If they are habitually cut down, there will be many ties left too long in the track. A marked saving in renewals may be effected by systematized checks and the preparation of careful estimates of each season's requirements. In this respect practice varies very widely, some roads being very careful and others very careless. The section foreman should determine by actual count, and not by a guess estimate, the number of ties on each mile of his section, which he considers will need to be renewed. This will be reported to the roadmaster, who should personally verify the estimate, in company with the foreman, so as to educate him, for while ties are often left in too long, yet many foremen condemn ties which are still good. On the Chicago & Northwestern Ry., each foreman marks with an axe the ties which he thinks should be removed, after which the roadmasters go over their divisions to check the foreman's judgment, and they generally cut down the estimates very considerably. Ties should never be renewed without permission, and those taken out should be piled up and not burned or removed until inspected by some officer thoroughly and practically familiar with the

use of ties and the amount of work that can safely be got out of them. On some roads the foremen are forbidden to remove ties having more than 4 ins. of good timber left under the rail.

The practice on the Illinois Central Ry. and some other large roads is practically as follows: The supervisors (who have charge of about 100 miles) personally walk the track with their section foreman and make a memorandum of the number of ties in each mile that in their judgment needs renewal. The reports (showing the number for each mile) then go to the roadmasters (who have charge of about 300 to 500 miles of track), the division superintendents, the assistant general superintendent, and the chief engineer. The roadmasters and division superintendents take the reports and personally walk over individual miles to check the judgment of the officers below them. The chief engineer, with the assistant general superintendent and the division superintendents, also pick out certain miles, walking the track and counting the ties, in order to check the judgment of the division officers and roadmasters. In preparing the final requisition, these reports are considered, together with the normal renewals for a period of ten years, the number of ties removed, and the officer's general judgment as to the necessity for these renewals. This system has an important influence in educating all the officers who work under it, and in effecting an economy in tie renewals. After the old ties have been taken out, in the spring, they are piled up and inspected by the officers concerned before they are destroyed or used for other purposes.

On the Louisville & Nashville Ry. an estimate of the number of ties required on each division is prepared prior to July, the estimate being made from actual count of ties that should properly be renewed during the next twelve months. The count is made by the section foremen, checked and certified to by the respective supervisors and roadmasters, approved by the superintendents after investigation, and forwarded by them to the chief engineer, who is supposed to have a general knowledge of the condition of ties on the entire line. If the requisitions differ widely from what he expected, they are returned for further investigation, and revised if necessary. Finally, the requisitions are forwarded to the general manager with a request for authority to contract for the ties needed. With them is sent a statement showing the average number of ties used per mile on each division during the ten years previous, and where the number called for appears excessive as compared with the average, an explanation is given. On the New York Central Ry., the supervisors personally examine the ties before July, and prepare a statement of the number required for renewal.

Records and Marking.—One great defect in the management of the track department is the neglect to keep reliable records from which the average life and cost of ties of different kinds can be computed. Without such records, the calculations and estimates of comparative durability and economy of different ties (treated and untreated) are little more than guess work. The keeping of these records upon some uniform and carefully formulated system is a duty that might properly be imposed upon the division roadmasters or officers of similar position. The record should include the cause of tie renewals (decay or rail cutting), and should keep ties in side tracks separate from those in main track. As a rule, the only statistics kept show

the number of ties removed on a certain length of line, without regard to the wood, the ballast, or other influential conditions. And even such statistics are not kept in a uniform manner. From systems of records proposed by the writer (Transactions, American Society of Civil Engineers, April, 1899), and by the Tie Committee of the American Railway Engineering & Maintenance of Way Association, the following list of headings for a tie record on each division has been prepared. It will, of course, be difficult to secure the adoption of such a system, but a beginning should at least be made, and the matter left to develop:

Information for Tie Records.

1. Length of first main track, miles.
2. Length of all main track, miles.
3. Average number of ties per mile.
4. Average number of ties renewed per mile.
5. Percentage of renewals to number in track.
6. Total number of ties renewed.
7. Kinds of ties.
8. Number of each kind renewed.
9. Cost of new ties.
10. Place where new ties were obtained.
11. Date when the old ties were laid.
12. Percentage of main line tracks curved.
13. Percentage of main line tracks tie-plated.
14. Percentage of main line tracks ballasted.
15. Percentage of main line tracks laid with treated tie.
16. Number of tie-plates per rail.
17. Kinds of ballast used.
18. Weight of rail.
19. Preservative treatment employed.
20. Average cost of treated ties at distributing point.
21. Average cost of untreated ties at distributing point.
22. Total cost of tie-renewals per mile of first main track.
23. Total cost of tie-renewals per mile of all main track.
24. Gross tonnage of trains passing over each main track.
25. Gross tonnage of trains per tie renewed.
26. Maximum weight of locomotive and tender, tons.
27. Number of ties renewed in side tracks.
28. Percentage of ties renewed in side tracks.
29. Number of old main line ties put in side tracks.

It is desirable to mark the ties in some way so that their length of service can be ascertained and recorded. As a general thing, this is entirely overlooked, and except for the more or less reliable memory of some foreman or roadmaster, there is no means of ascertaining the life or history of ties in the track. This is particularly troublesome in the case of treated ties having a long life. The renewals would be made irrespective of the marks, because the great difference in the enduring qualities of ties apparently from the same place and lot make it possible that some ties may last 8 years while others will last only 4 or 5 years. On the Allegheny Valley Ry. each tie is marked at the time of putting it in the track by cutting a small V-shaped notch in the edge with an adze or axe, the position of the notch indicating the year. The ties are hauled in from the woods in the winter months, and are usually placed in the track early in the year, so that a glance at the marking while passing along the track will show the observer both the age of the tie (from the tree) and its length of service. The section foremen make simple reports of the ties taken out, and their life as indicated by the marks, which reports are tabulated and filed, forming a record of the average life of the ties.

On the Cleveland Division of the Cleveland, Cincinnati, Chicago & St. Louis Ry., a method was adopted in 1892 or 1893 for marking the ties when put in the track, in order to secure definite information as to the length of service and life in the different kinds of ballast. For this purpose a 3½-lb. stamp hammer was used, with two figures about 1½ ins. long, ⅛-in. in relief, indicating the year. The stamp was used like a sledge, stamping the

number on the top and on the south end of the tie. After about three years service, however, this was discontinued, a large proportion of the marks having disappeared by that time. The Lake Shore & Michigan Southern Ry. and the Southern Pacific Ry. have used similar hammers since 1893, and find the marks generally still visible. The hammers have only one very large figure. A better method is to use marking nails, and the Chicago Tie Preserving Co. drives into each tie a ¼-in. galvanized nail, 2½ ins. long, with a circular head ⅝-in. diameter having the two last figures of the date of the year stamped into it. In Germany it has been found that the impressions made by hammer stamps on preserved ties became effaced before the time for renewal, and nails or tacks with distinguishing figures or marks were substituted. The Atchison, Topeka & Santa Fe Ry. stamps its treated ties and requires them to be laid with the mark at one side of the track. The section foremen report monthly, on a special blank, the number of treated ties removed and the cause of removal, these reports being for future compilation.

Old Ties.—Ties which are taken out and are not good even for sidetracks may be used for fence posts, for cribbing in wet slopes and for various incidental purposes, but are usually burned on the right of way or used for fuel. Old ties and bridge timbers intended for fuel may be economically cut up by machinery. The Murphy machine, used on the Pittsburg, Fort Wayne & Chicago Ry. and other roads, resembles a shearing machine. The upper (moving) blade is set about 1 in. out of line from the lower (fixed) blade, thus allowing old spikes or bolts to pass through without injuring the knives. The machine will cut timbers 8 × 16 ins., and has an attachment with knives by which the wood is split lengthwise to the size desired. The Chicago, Burlington & Quincy Ry. cuts the timbers to length by a circular saw, and then splits them by a 500-lb. drop hammer operated by a 6-in. vertical air cylinder 4½ ft. long. The Chicago & Western Indiana Ry. uses a cutting and splitting machine whose knives are operated by two air cylinders. Where ties have been burned or cut the ashes or chips should be raked over for old iron, which has an intrinsic value in the scrap heap.

Tie Plugs.—These are used to fill old spike holes, whether spikes are to be driven in the same place or not. It is usually economical to use machine-made plugs, and elm is the most satisfactory wood for the plugs.

Preservative Processes.

A few important lines have taken up the question of treated ties, and after investigation and experiment have introduced these ties quite extensively, with marked success. In general, however, the use of preservative processes for wooden ties as a means of securing improved track with reduced maintenance expenses has not been given the careful attention by railway officers which its importance warrants, and although the resultant practical economies have been amply proved in this and other countries, they have been accorded little recognition. This is due largely to the failure to properly appreciate the economics of the tie supply question, or the expenses involved in tie renewals, as above noted, with a consequent disinclination to incur an additional initial outlay to obtain permanent economy. Reports of foreign experience are apt to be regarded with some degree of distrust on account of the difference of conditions of railway construction and opera-

tion, but there is evidence enough in this country as to the efficiency of the preservative processes and the economies resulting from their use. While a first-class tie would be somewhat expensive when treated, yet the use of preservative processes enables cheaper and (if untreated) inferior timbers to be used at about the same cost as (or even much less cost than) untreated ties of a more expensive timber. This will enable much high-class timber to be left for other industrial purposes. Thus, mountain pine ties that last only about 3½ to 4 years, and sap pine ties that last only 2 to 3 years, have been proved to last from 9 to 12 years and from 7 to 10 years, respectively, when treated, being thus superior even to white oak in life and in regard to the work of tie renewals. The same applies to many other species of timber in greater or less degree.

Even if the first cost of the treated ties should be equal to that of untreated ties, the longer life would reduce the annual cost, and would also materially reduce the expenses for maintenance of way. The question of the relative cost and ultimate economy of treated and untreated ties comes up periodically for discussion, and engineers very generally recognize the practical and financial advantages of the former. Managers and executive officers, as a rule, however, see mainly the extra first cost for ties or a treating plant, or regard the matter as a very doubtful experiment, and are apt to doubt the economy of using very cheap and inferior woods. They do not yet sufficiently appreciate the economies due to increased life of ties and the savings of labor in renewals, so that a campaign of education must be conducted to bring about any general use of treated ties.

The following is taken from a detailed estimate prepared by a railway manager in regard to the relative cost of certain treated and untreated ties. The specifications for untreated ties of Southern pine generally call for all-heart pitch pine of such dimensions that 22 to 23 ties are equivalent to about 1,000 ft. B. M. To cut three such ties from one log requires a tree about 12 ins. diameter at the small end and 30 ft. long. Such logs are worth 30 to 35 cts. each as saw logs, and are becoming more expensive and farther removed from the line of railways and water courses. The logs generally used for ties are such as are defective for sawmill purposes, and are sold standing in the woods at 10 to 15 cts. each, or about 5 cts. per tie. The cutting of a tie costs from 12½ to 15 cts.; the hauling from the woods to the railway or landing, 3 to 5 cts; railway freight or lighterage, 5 to 15 cts.; making a total of 25½ to 40 cts. per tie at Southern port. The freight to New York ranges from 18 to 21 cts. per tie, and with the inspection and the percentage for loss or profit, the cost of a tie delivered at New York would be about 55 to 70 cts. Such a tie will have a life of about 5 years in the South and 7 years in the North, but in the North the wear under the rail and the checking of the timber are quite as destructive as decay.

Pitch pine is not suitable for creosoting, as it would not absorb a sufficient quantity of the oil, and short-leaf yellow pine is more suitable, having a more open grain. This timber grows near the coast and watercourses of South Carolina, Georgia and Florida in great abundance and very rapidly. It is in little or no demand for sawmill timber, and is consequently much cheaper than heart or pitch pine. It is not so hard and durable, but it does not check, and can be made as hard as, and more durable than, pitch pine by creosoting. The cost of the material in a tie is about 3 cts.; cutting,

12½ cts.; hauling to landing, 1½ to 3 cts.; transportation to port, 3 to 5 cts.; making a total of 20 to 23½ cts. at the port. Adding freight to New York, as before, and the expense of inspection, percentage of loss and profit, etc., would make the cost per tie 48 to 54 cts. delivered at New York. The creosoting would cost about 40 cts., so that the total cost for a creosoted tie would be about 85 to 94 cts. From the figures given below it will be seen that the actual annual cost of the two ties, taken as a minimum, will be about the same on a road which can borrow money at 4%. With a higher rate of interest or a higher price for the untreated tie, there would be a greater difference.

	Ties	
	Untreated.	Treated.
Average life	6	12
Average first cost, cts.	50	90
Annual interest charge on first cost at 4%, cts.	2.0	3.6
Annual outlay for a sinking fund which will replace tie at end of its life (4% interest), cts.	7.7	5.6
Total cost per tie per annum	9.7	9.2

On roads where a fairly good quality of timber is used for treating, the economy will be in the maintenance expenses rather than in the cost of the ties themselves. But on roads using good and expensive untreated ties, or where the ordinary ties have but a short life, or where a road is so located that good ties are very expensive and the available ties are very poor, there may also be a very material saving in the cost of the ties themselves. In fact, most of the progress in the way of tie preservation has been made by the railways of the far south and west. As an example of the results, the Southern Pacific Ry. has found that by the use of burnetized ties since 1887, the tie-renewals were reduced from 243 per mile of track (including sidings) in 1891, to 240 in 1892, 203 in 1893, and 145 in 1894. To arrive at any definite conclusion in regard to the advisability of using treated ties on any particular railway, it is necessary for the officers to carefully and thoroughly consider for themselves the relations of expenses for ties and tie renewals and track work, and the cost and life of treated and untreated ties under the conditions of location and traffic of that particular road.

In most of the processes, the principle of the treatment is to extract the sap and replace it (under pressure in closed vessel) by a material which will fill the cells of the wood and prevent fermentation and decay. The vessel is a horizontal cylinder, with a narrow gage track for steel cars loaded with ties. The timber should be thoroughly seasoned before treatment, and the ties should be allowed to stand for some weeks after treatment, before being put in the track, in order to allow the chemicals to become permanently settled in the wood. It is waste of time and money to hurriedly treat fresh timber for immediate use, though this is sometimes done, owing to contracts for ties not being placed in time. Each charge of the treating cylinder should be composed of ties of about the same age, to ensure a uniform result. Each car or buggy load of ties should be weighed as it passes in and again as it passes out of the cylinder, and any load showing an insufficient amount of absorption should be treated over again. Whatever process is used, it is absolutely essential that it should be carried out carefully and thoroughly, if the best results are to be obtained. For this reason, among others, several large railway companies prefer to operate their own plant, which plan is likely to give satisfactory

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and economical results if the work is carried on systematically. The various processes used, their efficiency and economy, and the results obtained with them, will be found very fully treated in the following publications: Report of a committee of the American Society of Civil Engineers, 1885; Bulletins No. 1 and No. 9 of the Forestry Division, U. S. Department of Agriculture, by Mr. P. H. Dudley and the writer; a paper on "The Preservation of Railway Ties," by Mr. W. W. Curtis, Transactions of the American Society of Civil Engineers, 1899; and papers on "The Preservation of Timber," by Mr. O. Chanute, Journal of the Western Society of Engineers, April, 1900, and Transactions of the American Society of Civil Engineers, September, 1900.

Creosoting.—This process consists in impregnating the timber with creosote oil. It is very extensively used abroad, but its introduction in this country has been hindered by the higher cost of creosote oil, and the consequent expense of the treated ties. While it is undoubtedly the best process from a chemical point of view, yet from a commercial and economic point of view it cannot compare with the zinc processes, which very effectively preserve the ties at much smaller cost. The stages of the process are essentially as follows: (1) Placing the ties in the cylinder and exhausting the air; (2) heating the ties by steam to soften the cell walls and dissolve the contents of the cells, (3) again creating a vacuum to draw the sap out of the wood, and then (4) filling the cylinder with hot creosote oil and applying pressure to force it into the wood. The creosote is heated to make it sufficiently fluid to thoroughly penetrate the wood. Two kinds of oil are used: dead oil of coal tar and wood creosote oil. The dead oil is obtained by the distillation of coal tar, and its principal preservative constituent is naphthaline. This melts only at about 175° F., and if liquefied during the treatment it penetrates the wood cells and then becomes solidified and permanently fixed. Acridine is an important constituent and this also remains permanently. The tar acids, which were formerly supposed to induce coagulation of the albumen in the tie, and thereby to be the principal preservative, are found to disappear in a comparatively short time. Wood creosote oil is obtained by the destructive distillation of pine, and contains paraffine oils, which have been claimed to act as preservatives. Their value is very much questioned and the material does not meet with much approval. One analysis is as follows: tar, 10%; tar acids, 36.7%; neutral oils (mostly paraffine oils), 53.3%.

The ties should be well seasoned, as a wet tie will absorb but little oil, while a thoroughly dry tie will readily absorb a large quantity which, when solidified, is not affected by moisure in the air or ground. The oil should be thoroughly forced in, and, if possible, any cutting, framing or boring should be done before the tie is treated. The absorption is about 8 to 12 lbs., or 1 to 1½ gallons, of creosote per cu. ft. of timber. A common objection is that creosoting softens the wood and renders it more easily cut by the rail. This effect, however, is only temporary, and if the ties are stacked for about six weeks after treatment, no trouble is likely to be experienced. The weight of the oil is about 8.7 lbs. per gallon. The Southern Pacific Ry. specifies that it must be produced in the manufacture of bituminous coal gas, be completely liquid at 100° F, and have no deposit take place above 90° F. It must contain 7 to 10% of tar acids and 20 to 30%

of naphthalene, and when distilled at 600° F must have from 20 to 35% of undistilled residue. The details of operation at the works of the Southern Pacific Ry., near Houston, are as follows:

A charge of ties is run in, the cylinder closed, and a vacuum of 24 to 26 ins. is created, requiring about 10 minutes. Live steam is then turned in, destroying the vacuum and giving a temperature of about 250° F (15 to 20 minutes). The vacuum pump again creates a vacuum to open the wood cells and to have the cylinder heated uniformly (15 to 20 minutes). Live steam is again turned on, and the pressure raised to 15 or 20 lbs. in about 40 minutes. This is maintained from 6 to 8 hours, according to the size and kind of timber, care being taken to prevent the temperature from exceeding 250° F. Steam is then blown off (40 minutes), and a third vacuum created of 24 to 26 ins., requiring about 90 minutes. The superheating pipes in the cylinder maintain a temperature of 225° on the timber during these 130 minutes and during the 4 to 6 hours for which the vacuum is maintained. The cylinder is then filled with creosote oil at a temperature of about 170° F. (35 to 40 minutes). The pumps then raise the pressure to 80 or 100 lbs. per sq. in., which is maintained from 1 to 2 hours, according to the size and kind of timber. The oil is then drawn off, the cylinder opened, the train pulled out, and another charge run in, (40 to 60 minutes). The average time of treatment is 18 to 20 hours; the average absorption, 1¼ gallons per cu. ft.; and the average cost in 1898 was as follows: creosote oil, $8.26; fuel, 59 cts.; labor, $1.23; maintenance, 15 cts.; total, $10.23 per 1,000 ft. B. M. For piles, no vacuum is created, but the timber is boiled in the dead oil at a pressure of 120 lbs., and a temperature of 240° F., the treatment lasting 12 to 14 hours. As the checking occurs during the treatment, the resulting cracks are well filled with oil. Trestle timbers are also treated. The Southern Pacific Ry. has a portable plant for treating timber, which is set up on a sidetrack in the woods where the ties are being cut. (Engineering News, New York, April 4, 1895).

Burnetizing.—This process (also known as the zinc-chloride process) consists in impregnating the timber with a solution of metallic zinc in hydrochloric acid, and the method of treatment is similar to that above described, except that the solution is not heated. The chemical has the property of hardening the wood, and is said to make it brittle, especially if a solution of over 3% in strength is used, so that the process is not considered desirable for bridge timbers or piles. The Chicago Tie Preserving Co., however, has increased the strength to 5° Beaumé, without making the ties brittle, and it is thought that under modern methods of treatment this result may be avoided. The ties are said to be liable to split if exposed to a hot sun. The chloride in the ties is somewhat soluble. At the plant of the Atchison, Topeka & Santa Fe Ry. the solution contained about 1 lb. of chloride to 4 gallons of water, and the amount of chloride injected varied from 0.28 to 0.47 lbs. per cu. ft. of timber. The green ties of mountain pine cost about 12 cts. and would last only about 4 years. The treated ties cost 25 cts., and promise to last from 9 to 12 years. This plant has three cylinders, 6 ft. diameter and 106 ft. long, and the hewed ties are sawed to length and have the rail seats trimmed or "spotted" by machine (Engineering News, Sept. 13, 1894). The Wellhouse auxiliary process is now employed at both of the plants of this railway.

The process of burnetizing at the works of the Southern Pacific Ry. is very similar to that of creosoting, already described. The steam is held at 15 lbs. pressure for 3½ to 6 hours only. After the third vacuum, the cylinder is filled with the cold zinc solution, requiring about 25 minutes, and a pressure of 80 to 100 lbs. is then maintained for 1 to 1½ hours (according to the kind and condition of the timber), when the solution is drawn off (20 minutes). The solution contains 1.6% of the chloride of zinc, corresponding to 2.3° on the Beaume hydrometer. The average time of treatment is 11 to 12 hours; average absorption, 4½ gallons per tie 6 × 8 ins., 8 ft. long; average cost of treatment, 6 to 9 cts. The ties are marked with a dating stamp, and are piled for 6 to 8 weeks to allow the chemical changes to become permanently fixed. Sap ties of long-leaf and short-leaf yellow pine (from Texas and Louisiana) are used, costing about 23 cts. each at the mills, and having a life of only about 2½ years. Of 196,365 treated ties laid in 1889, there were 78% in the track in July, 1899. As the ties are laid mainly in a very dry region (west of San Antonio), there is no trouble from the chloride leaching out, as it may do in damp regions, and it was therefore concluded that no benefit would result from any auxiliary treatment to prevent such leaching. For the same reason, the new plant of the Burlington & Missouri River Ry. is for the plain burnetizing process, as the ties are to be laid in a practically rainless region. On the other hand, the Houston & Texas Central Ry. is arranging to use cypress ties in the coast country, where the excessive rainfall makes the life of burnetized pine uneconomically short. Of these latter ties, many are found to fail through the sapwood breaking off, leaving the heart like a pole with very little bearing area.

Wellhouse and Other Zinc-Auxiliary Processes.—In wet or damp locations the zinc-chloride (being soluble) may be leached out by the dampness in the atmosphere and the ballast, and several auxiliary or combination processes have been introduced to seal the wood cells after the impregnation has been completed. The best known of these is the Wellhouse or zinc-tannin process, which has been extensively applied in this country. The operations at the portable plant on the Chicago & Eastern Illinois Ry. (treating water, red and yellow oak) are as follows: When the cylinder is closed, the air is exhausted by a pump, and live steam at 20 lbs. pressure is admitted for 3 hours, the temperature within the cylinder not being allowed to exceed 200° F. A vacuum is again maintained for 1 hour, to cause the sap to flow, the liquid being then drawn off. The cylinder is then filled with a zinc-chloride solution of 3% to 4% strength, which is retained under 100 lbs. pressure for 2 hours or more. The cylinder is then emptied and filled with the gelatine solution; again emptied and filled with the tannin solution, both under 100 lbs. pressure for 1 hour. The absorption averages 31 lbs. per tie (Engineering News, Aug. 17, 1899). By applying the three solutions separately, a much greater penetration and absorption are obtained, as the zinc solution (which is the preservative) is very fluid, while the other solutions (which are to close the cells) are thick and ropy, and penetrate but a short distance. Under the other method glue is added to the zinc solution (2 lbs. of glue per gallon of solution), and the tannin solution is applied separately. The tannin and gelatin (or glue) combine to form a waterproof leathery substance which permanently closes the outer cells of the wood, excluding the damp and retaining the zinc. Ties treated by this process are very ex-

tensively used by the Chicago, Rock Island & Pacific Ry., and Atchison, Topeka & Santa Fe Ry. The treated hemlock ties sometimes outlast untreated oak ties, owing to the hardening effect of the treatment.

In the zinc-creosote process, as employed in this country, the timber is first impregnated with a 2% solution of chloride of zinc (giving 12 lbs. of solution per cu. ft. of timber, and is then treated with creosote (about 3 lbs. of oil per cu. ft.) in order to seal the outer cells. As used in Germany, a special quality of creosote oil is added to the zinc solution in the proportion of 4.4 lbs. of oil per tie, or 1.25 lbs. per cu. ft. of timber. This process has also been used to a limited extent in this country. A zinc-gypsum process has also been tried on a small scale.

Kyanizing.—This process consists in steeping the ties in open tanks in a solution of about 1 part of bichloride of mercury (corrosive sublimate) to 100 parts, by weight, of water; or 1 lb. to 8 or 10 gallons. One day is allowed for each inch of thickness of the wood. Care is necessary, as the material is an active poison. It hardens the wood, but is generally more satisfactory for timber that is kept dry. The Boston & Maine Ry., however, used kyanized hemlock ties at one time, and found that the process paid when well done.

Thilmany.—In this process the ties are first impregnated under 80 to 100 lbs. pressure, with a solution of sulphate of zinc (or sulphate of copper, but this is more expensive), and then a solution of chloride of barium. These form a chemical combination of insoluble sulphate of baryta and chloride of zinc. It has only been used experimentally for ties, and unsatisfactory results are reported, owing apparently to the combination failing to take place thoroughly in the small wood cells.

Boucherie.—In this process a solution of 1 lb. of sulphate of copper to 100 lbs. of water is applied, either in a cylinder or by a cap fitted to one end of a log or tie, the solution being forced through by pressure or vacuum. It would require about 80 to 100 hours for the solution to travel through a log as long as a tie. The rails and spikes decompose the solution, producing free sulphuric acid, which attacks the fibers of the wood.

Vulcanizing.—This is a modern American process, and differs from those above described in that no impregnating solution was used. The timber was placed in the cylinder and subjected to an air pressure of 100 to 175 lbs. at a temperature of 300 to 500° F., which treatement was claimed to chemically change the sap into a preservative composition. It is stated on good authority that there is no knowledge of the physiology or chemistry of wood to sustain this claim, and tests made by the U. S. Forestry Division showed no increase in strength and no chemical or physical change. Tests have also shown that the temperatures claimed did not reach the interior of the tie. It is simply a development of a seasoning process, and with resinous woods it may effect a more complete distribution of the resinous matter, which is in itself of a preservative character. Vulcanized pine has been used for ties, guard timbers, station platforms, etc., on the New York elevated railway, and a few experimental ties were laid in 1895 on the New York, New Haven & Hartford Ry. near Rowayton. In 1899 they were reported as showing no signs of decay, but it was too early for any definite conclusion. The vulcanizing process proper is now supplemented by a treatment with creosote, formaldehyde and resin, and a final treatment with

resinate of lime. The "vulcanizing" is claimed to sterilize the timber, but did not prevent decay of the outside.

Miscellaneous.—Fernoline, spirittine, pinoline and woodiline are preparations resembling wood creosote oil, and are used either as a bath for ties, poles and timber, or as a paint for bridge and station timber, planking, piles, ferryboats and scows, etc., to prevent decay and the attacks of boring worms. The Pennsylvania Ry. wood preservative for such purposes is a distillate from Georgia pine. The specifications require 5% tarry matter (not over 12%), 45% tar acids (not less than 30%), 50% neutral oils; flashing point, 172 to 200° F.; burning point, 200 to 220° F.; running point, 15 to 20° F.; specific gravity, 1.03 to 1.05. The bath is usually heated to about 150° F., but the Pennsylvania Ry. has tried heating the ties and dipping them in cold woodiline. A dry oak tie will absorb about 1½ gallons of this in 3 hours, but ordinarily the immersion is only for 15 minutes, giving an absorption of ½ gallon. The cost is about 15 to 20 cts. per tie, including material and labor. Carbolineum and Finch's preservative are applied for similar purposes in a similar way. The former should be heated to about 250° F. and the timber given two good coats, allowing 24 hours between the applications, and between the time of the second coat and the time of using the timber. For filling old spike holes, tar or refuse resin from the turpentine distilleries are superior to wooden plugs, but are awkward to use. When piles (treated or untreated) are left with the heads exposed, as in the case of fender piles, the heads should be well coated with tar, which is better than creosote oil, as it forms a mechanical cover to exclude the moisture. On framed work for bridges, trestles, docks, etc., the framed portions may be well painted with some preservative before being put together.

Metal Tie-Plates.

There is usually considerable trouble from the cutting of soft wood ties by the rails, as already noted, and this is aggravated by the resulting local rot under the rails and around the spike holes, and by the further wear and disintegration of the softened wood. The cutting also decreases the hold of the spikes, letting the rail drop loose below the spike head and allowing it to get out of gage and to tilt on curves. The direct pressure of the rail on the tie has little destructive effect, but it is the slight wave motion of the rail which causes the cutting, grinding and abrasion of the wood, and the wear or "necking" of the spikes. One of the most important and practical of modern improvements in railway track is that effected by the introduction of metal tie-plates, which are placed between the rail and the tie. They involve only a small additional cost, but effect a most decided economy in ties and in track work. In some exceptional cases, where they have been put on old ties, a saving of over 50% in track work (mainly for maintaining gage) has been effected. They act as a tie protector or preservative, and are in no way to be classed with the chairs and joint chairs (obsolete in this country, but still extensively used abroad), whose office was to support the rails and hold them in position.

The small and light tie-plate which embodies its own fastenings to the tie, and becomes an integral part of the tie, independent of spikes, bolts, etc., is a distinctive feature of American railway track. It is a decidedly modern invention, but has fully borne out the ideas of its designers, and is

now very extensively used, while its application is spreading rapidly. The cheapness of tie-plates, combined with their undoubted advantages in efficiency and economy, has led to their adoption on many hundred miles of track. It is recognized that they not only increase the life of ties of durable but soft timber (whether treated or untreated), but also effect a direct economy in renewals and maintenance of way, while at the same time they add to the permanence and security of the track by giving a durable and uniform bearing to the rails, and lessening the disturbance of track for tie renewals. They are specially advantageous for soft ties under heavy traffic. It was at first predicted that they would make it difficult to keep the track in gage, but the very opposite has been the result. They prevent the widening of the gage which occurs (particularly on curves) by the tilting of the rail as the lateral pressure causes the outer edge of the rail base to cut into the wood. They also cause the spikes on both sides of the rail to act equally to resist the outward lateral pressure; the plate ties the two spikes together and is thus equivalent to double spiking, making the two spikes as efficient as three. On curves they have been successfully used in place of rail braces, for the above reasons, as the great trouble (especially on sharp curves at switches and turnouts) is the tendency to tilt the rail in the manner above described. On steep grades, the plates prevent the increased cutting of the ties due to sand from the engines getting under the rail and helping to abrade the wood.

Tie-plates may be used with special advantage as follows: (1) At terminal yards, where, on account of frequent switching and the use of sand, the rails cut into the ties very soon, while tie renewals are difficult and expensive, and interfere with traffic; (2) on curves, to save the uneven wear of the rails and the loss of thickness in the ties by frequent adzing of the rail seats; also to save the frequent lining and respiking, and to maintain correct line and gage to ensure easy riding curves; (3) at switch leads on main track, under the rails that cut into the long ties, thus saving expensive renewals of ties otherwise perfectly good; (4) at rail joints on tangents (whether suspended, three-tie or supported joints), to hold up the rail ends and prevent them from deflecting by cutting into the ties; (5) on tangents where ties are cut out by the rails before they decay; (6) on bridges and trestles. The plates may be used on every tie on bridges, trestles, curves, etc., and on tangents where soft ties are used. With good, hard ties they are sometimes used only at joints and quarter ties; or 6 to 10 plates to each rail.

Flat-Bottom Tie-Plates.—The objection to a simple flat plate is that it is impossible (with spike fastenings) to keep it tight, so that there will be a continual movement of the rail on the plate and the plate on the tie, with a consequent admission of dust and moisture to cause wear and decay. At the same time, there will be a constant clattering under traffic. Flat plates that are thin and wide will bend and buckle, while if made thick enough to resist bending, they will be clumsy and heavy. The New York elevated railways laid some flat plates 6 × 8 ins., ¼-in. thick, in 1888, but in addition to buckling and cracking at the ends, they induced premature decay of the yellow pine ties. They rattled under the trains, and kept the moisture on the ties, thus hastening rot, especially in summer, when the plates were hot and the ties damp. In 1894, ties which had been in service less than 6 years

had to be removed because of the decay thus caused. In some ties the rot extended to the sap wood beyond the plates, while in heart wood it was confined to the part covered by the plates. As a result of this experience, flanged plates were adopted and are now extensively used on these lines. The Southern Pacific Ry. at one time used flat wrought-iron tie-plates to protect the soft redwood ties on the Pacific lines. The plates were 9 x 7½ ins., ⅜ to 7-16 in. thick under the rail, and having a rib to receive the outward thrust of rail base and four 11-16-in. round holes for screw spikes. The weight was 6⅓ lbs. They were not satisfactory, however, and since the introduction of flanged tie-plates their use has been discontinued.

Flanged and Toothed Tie-Plates.—To effect an attachment of the plate to the tie, various arrangements of flanges, spurs and teeth have been devised. The object should be to secure a firm hold and to do as little injury as possible to the wood. This appears to have been most efficiently attained by providing the plate with longitudinal flanges, which are forced into the wood and are tightly held by the fibres, while the size of the flanges is such as not to split or crush the wood. The fibres are compressed between the wedged-shaped flanges, and the flanges also serve to stiffen the plate, and enable a thin plate to be used without buckling under heavy loads. Long experience with plates of this type show that they become immovably fixed upon the tie, do not cause checking or cracking, and do not cause decay to set in. For plates with chisel-edged claws or spurs cutting across the grain, it is claimed that the grip is equal to that of four good spikes, but such plates must rely on their thickness for stiffness. The objection that outward thrust on the plate will force out the fibers cut by the spur does not seem probable, except in very soft and poor ties. The more serious objection is the direct cutting and severing of the fiber. The Churchward plate had six teeth, 1 in. long and of triangular section, to bite into the tie, but this plate is now very little used.

Ribbed Plates.—Some plates are made with a rib on top, against which the outer edge of the rail base is fitted. It is claimed that one of the important functions of the tie-plate is to relieve the spike from the outward thrust of the rail and the wear due to abrasion by the edge of the rail base, and this certainly seems reasonable when we consider the inefficiency of the spike as a fastening for rails under heavy traffic. On the other hand, it seems to be the general opinion that the flat-top plates, which have been used much more extensively and for a longer time than any other form, have been found entirely satisfactory in this respect, and that there has been little or no "necking" of the spikes, even on sharp curves, provided that the rail base is the full width between the spike holes and that old "necked" spikes are not redriven. In other words, there has been no trouble where full contact and an absence of play are ensured in the first place, as, of course, they should be in good track work. This applies even to sharp curves in switch leads used by heavy engines.

Dimensions of Tie-Plates.—The plates should be large enough to give a good bearing on the tie, with room for the spike holes, but very wide and very narrow plates are equally objectionable. If too large, they are more liable to buckle, while a very wide plate will not allow for the wave motion of the rail. Experiments with plates the full width of the ties showed that they caused the ties to rock in the ballast. Plates 4½, 5 and 6 ins. wide, and

8 or 9 ins. long, are now most generally used. The Southern Pacific Ry. uses four-flanged Servis plates 5 x 8 ins. on intermediate ties, and three-flanged plates 6 x 9 ins. on joint ties. The New York Central Ry. uses the same type of plate, 6 x 9¾ ins., 13-16-in. deep over all, on the middle tie of its three-tie joints. The larger plates, with four spike holes, may also be used on very sharp curves. The thinner the plate, as long as it is able to resist buckling, the better it will hold to the tie, and the flanged plates are usually about 3-16-in. thick, while those having no stiffening flanges are from ¼ to ½-in. thick. Experience has shown that the wear of the plate by the rail is very slight, except in some exceptional cases, so that great thickness is not required to resist such wear. A thin plate, which will not buckle or work under the traffic, would therefore appear to be as efficient as, and more economical than, a thick and heavy plate.

Application of Tie-Plates.—The plates should be properly set and bedded on the ties in the first place, and not left to be driven home by the weight of the trains. The traffic will not do this efficiently, and meanwhile there is a liability of gravel, etc., getting under the plates and preventing them from being properly bedded. Unless the plate has a full even bearing on the tie it is likely to fracture under loads. In laying these plates, the line side of the tie is marked and the plate put on at the proper distance from the edge. The other plate is then set in its proper position by a gage. The exact position depends, of course, upon the width of the rail base. The plates may be forced into the tie by a machine at the shops, by a portable hydraulic press, or by a paver's rammer (striking vertically). The most general method, however, is to use a maul or beetle of about 15 to 20 lbs., with a 36-in. handle, a wooden or metal block or follower being put on the plate to distribute the force of the blow. Unless this is done, a careless man may bring the edge of the maul upon the plate, buckling it so that the rail will rest only on its two edges. In applying plates to ties already in the track, the rail may be lifted, the plate slipped under, an iron plate placed upon each projecting end, and these two plates struck simultaneously with mauls. One end of the flanged plate may be settled into the tie, and the free end then driven with a sledge, causing the flanges to plow their way through the wood under the rail. Special tools are used for setting the plates in right position. (See Tools and Maintenance.). Considerable economy in track work may be ensured by placing the plates on new ties for renewals before the ties are put in the track. When plates are put on old ties, a flat seat must be adzed or the ties may be turned. In the construction of the San Francisco & San Joaquin Valley Ry. (1898-99) the ties were unloaded in the material yard and put through a tie-plating machine, which gaged the plates and drove them to place by steam power, one movement of the lever driving both plates home. It was found that the ties could then be stored, loaded on cars, shipped to the front, and put into the track without a loss of plates, and this method gave exceptional results as to cheapness and as to effective bedding of the plates. As the track was laid, the plates which came under joints were removed and joint tie-plates substituted at very small expense.

Shimming.—The tie-plate is intended to be a permanent part of the tie, and no attempt should be made to remove the plate when shimming is required. In fact, it would be very difficult to remove it. The shims should

be placed between the rail and the plate, being bored to correspond with the spike holes in the plates. Where shims more than 1½ ins. thick are required, a piece of plank should be spiked to the tie and the shims placed upon it. If the traffic is very heavy, a second tie-plate may be placed on the shim.

Examples of Tie-Plates.—The Servis or Q. & C. tie-plate (Fig. 18) was the first to be introduced to any practical extent, and has been more extensively used than any other. It is usually 3¾ x 8, 5 x 8 or 6 x 9 ins., 3-16-in. thick, with three or four flanges about ¾-in. deep. The spike holes are punched to fit the rails to be used, and four holes are sometimes punched in plates for joints on sharp curves. The Wolhaupter plate had longitudinal flanges, but closer together and with more sloping faces to compress the fibres. It had also grooves on the face of the plate to receive any sand, etc., that might get under the rail, and lugs or shoulders to fit the outer edge of the rail base. The Q. & W. plate, Fig. 19, is a combination of the best features of the two former, both of which it has practically superseded. It has longitudinal flanges and grooves, but no lug or shoulder. The metal is 3-16-in. thick, and plates 4½ x 8 ins. and 5 x 8 ins. weigh about

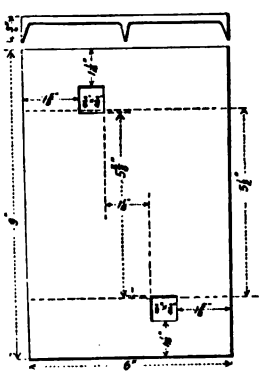


Fig. 18.—Servis Tie-Plate.

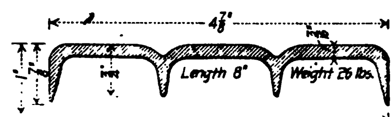


Fig. 19.—Q. & W. Tie-Plate.

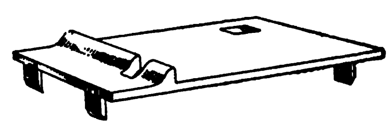


Fig. 20.—Goldie Tie-Plate.

2¼ and 2¾ lbs. to 3 lbs. The 5 x 8 size is most generally used, but larger sizes are also used for special cases, and weigh 4 to 5 lbs. The Goldie tie-plate (Fig. 20) is 7½ ins. long, 6 ins. wide and ⅜-in. thick, weighing about 5 lbs. It has a rib on top, and at each corner is a flat chisel edge or pointed lug which is driven into the tie, cutting across the grain. There are other forms of tie-plates in use, but all more or less closely resembling those above described, which are the ones most extensively used. The Churchward plate had teeth on the under side 1 in. long and ⅜-in. high; it was about 6 x 9 ins., ½-in. thick, and weighed 4 lbs. Very few of these are now in use.

Foreign Tie-Plates.—Tie-plates of various forms have been used on foreign railways since 1838, but they are generally much heavier than the American plates, weighing 8 to 12 lbs. each. None of them are of the "self-fastening" type developed in this country, but require to be secured by spikes, bolts, or screws, the two latter fastenings overcoming to some extent the difficulties arising from the looseness of flat plates. Some of the plates

have a transverse rib fitting in a groove cut across the tie, to prevent the plate from slipping, but the cutting of ties in this way, or to let a thick plate lie flush with the top of the tie, is very bad practice. The Sandberg tie-plate (Fig. 21) is about 12 × 18 ins., ½-in. thick and weighs about 13 lbs. It

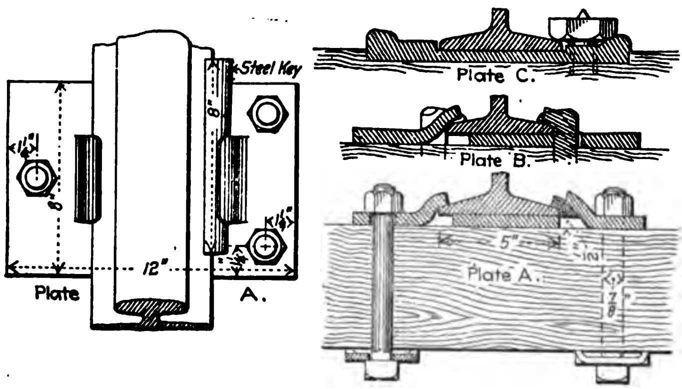


Fig. 21.—Sandberg's Tie-Plates.

is fastened by fang bolts, spikes or screw spikes, as shown, and has lugs to hold the rail base. The rail is secured to the bolted plate by a taper key driven between the rail base and one of the lugs. This plate was designed by Mr. C. P. Sandberg, the European rail expert, who has recognized that the cast-iron chair is a weak point in English railway track, and that with flange rails and tie-plates a track can be built more economical than, and equally as strong as, the track with bull-head rails in chairs. This is the view which the author has frequently expressed. The tie-plate designed by Mr. J. W. Post, of the Netherlands State Railways (inventor of the well-known Post steel tie), is shown in Fig. 22. As now made, however, the bottom is usually flat (except that it has the maker's mark in relief). It is 8.56 ins. wide, 8 ins. long, and 0.52 to 0.74-in. thick at the rail seat, which is 4.32 ins. wide, inclined 1 in 20. The outer edge of the rail base bears against

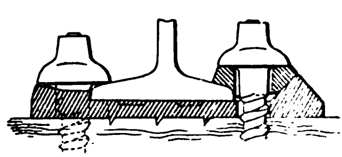


Fig. 22.—Post's Tie-Plate; Netherlands State Railways.

a shoulder on the rail seat and is held by a screw spike. The inner side is held by a clamp with a similar spike. The plate has three round 1-in. spike holes in each side. The standard track of the Prussian State Railways has 82.65-lb. T rails on flat-bottomed steel tie-plates, 7½ × 6⅛ ins., ⅛ to 11-16-in. thick under the rail, and weighing 8.82 lbs. The top surface is grooved to fit the rail base, and the plate is held by three screw spikes.

Metal Ties.

The use of metal ties is not likely to obtain in this country for very many years, and not until the era of preserved wooden ties, metal tie-plates and improved rail fastenings has become much further advanced. Nevertheless it will be well for American railway managers and engineers to consider the extensive experience with such ties in other countries, with a view to the possibility of their future introduction here. The trials made here, so far, have been few and unimportant, and they have generally been on too limited a scale to give any definite results. The experiments should be continued, however, in order to determine the life of steel ties under actual conditions of service, and also to develop the special features of merit or deficiency in the various designs. It is of little use to put in a few ties, but at least half a mile of track should be laid with them if any definite conclusions are to be obtained. Metal ties have passed beyond the experimental stage, and are now largely used in other countries, for main lines with heavy traffic as well as for secondary lines and pioneer railways. This is shown in the author's reports on "The Use of Metal Ties for Railways" (issued by the Forestry Division of the United States Government in 1890 and 1894). In 1894 there were 35,000 miles of railway laid with metal track, or 17½% of the total mileage of the world, exclusive of the United States and Canada, since metal ties are used to but an infinitesimal extent in the former and not at all in the latter.

The advantages of metal ties are in longer life, reduced cost and labor of maintenance, superiority of track, permanence of roadbed due to reduction in renewals and maintenance work, and a decided ultimate economy. Excellent and easy-riding track is made with good metal ties, but of the innumerable forms of ties which have been tried, only a comparatively small number have proved successful. The fastenings should be of as few parts as possible, without special fittings for curves or joints, and should provide for an adjustment of gage at curves, switches, etc. Some of the bolted clamp fastenings are found to remain tight and prevent rattling. To prevent noise due to the contact between the steel rail and tie, packings of felt, wood, asbestos, tarred canvas, etc., have been tried, but without much success, and there is little need of such packing with good fastenings that do not work loose. The ends of the tie should be closed, to resist lateral motion, and the friction of the core of ballast thus enclosed over the bed of ballast greatly increases this resistance. Broken stone ballast about 1 in. in size is generally best for main tracks, although close-packing coarse gravel is sometimes preferred. Wooden ties are generally used at frogs and switches, but long steel ties can be (and are) used, affording extra security. Ties bent and distorted by derailment, etc., can often be made serviceable again by straightening in a hydraulic press, as is done where such ties are used extensively.

Cast-iron and steel bowls and plates, connected in pairs by transverse tie-roads, are extensively and successfully used in India and South America, and have been tried in this country. The latest pattern used in India weighs 230 lbs. complete, and renewals average only 0.6 to 0.8% per annum. The most approved, and by far the most extensively used form of tie, however, is a rolled or pressed steel cross-tie of channel or trough section, with ends

closed, and laid inverted in the ballast. This is developed from the type of tie invented by Vautherin, the French engineer, in 1864. The design and manufacture of the tie and fastenings should be such as to ensure good material and accuracy of fit. Bessemer, Thomas and Siemens-Martin steel is used, with about 0.1 to 0.2% carbon, and having a tensile strength of about 50,000 to 60,000 lbs. per sq. in., with an elongation of 18 to 20% in 8 ins., and a reduction in area of 30 to 40% at the point of fracture. The steel of the ties for the New York Central Ry. was made soft to stand pressing to shape, and had 0.1% carbon, 0.4% manganese, 0.081% phosphorus and 0.033% sulphur. Corrosion occurs in certain saline soils, in ashes, etc., and the ties are usually dipped hot in a bath of tar. Cracks are less likely to start from drilled than from punched holes. The tie should be of simple design, and with the smallest number of parts consistent with security and the necessary adjustment; the thickness should be sufficient for strength and wear, and the weight sufficient to hold the track down well. From 120 to 175 lbs. is probably the best weight for a tie for first-class track carrying modern heavy engines and heavy rolling stock. Of the numerous designs of metal ties patented in this country, only an infinitesimal proportion have any practical value, owing mainly to the failure of the inventors to compre-

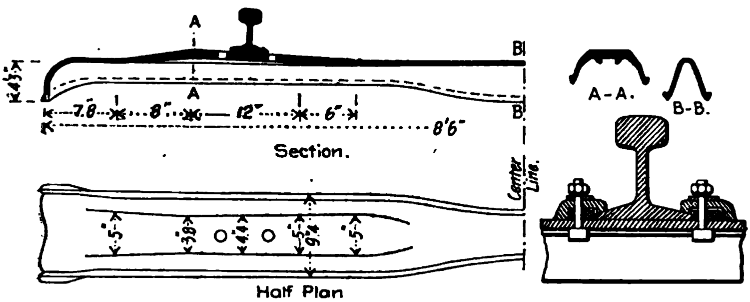


Fig. 23.—Post's Steel Tie.

hend or provide for practical conditions of service. Lightness and cheapness are too often aimed at as of first importance, with the result of making the tie practically worthless and extremely uneconomical; or in other cases the design is so unwieldy and complicated as to be entirely impracticable for manufacture or use.

The life of steel ties will vary from 20 to 40 years, and even 50 years is claimed. For the first 2 to 4 years the labor and cost of maintenance will be about the same as, or perhaps more than, with wooden ties, the expense being mainly on the ballast and the rail fastenings. The metal track, however, then becomes permanently consolidated and the attention required steadily decreases; with the wooden ties, however, the work and expense continue to increase year by year, until renewals are necessary. One of the great advantages of metal track is that it is not disturbed frequently for tie renewals, and is thus kept in good condition for running. A part of the Netherlands State Railways (Holland), laid with Post steel ties and carrying 25 trains daily, was carefully tamped and put in condition, and was then

left for 40 months without any other work than occasional tightening of the nuts.

Steel ties are extensively and successfully used in Europe, India, Africa, South America and Mexico. The Post tie, invented by Mr. J. W. Post, Division Engineer of the Netherlands State Railways, is used in many countries for lines of broad and narrow gage carrying light and heavy traffic. Fig. 23 shows this tie for standard gage track, its length being from 8 ft. 4 ins. to 8 ft. 10 ins. and the weight from 120 to 163 lbs. It is of varying section, being thinner, narrower and deeper at the middle than at the ends, thus combining strength and stiffness with an economical distribution of metal. The thickness is from 0.48 to 0.52 ins. at the rail seats, decreasing to 0.24 in. at the middle, while the sides are 0.24 to 0.36 in. thick. At the middle the tie is 4½ ins. deep and 5½ ins. wide over the bottom, with sides sloping 1 to 3. At the rail seats it is flat for 4½ ins. on top, 10¼ ins. wide over the bottom, and 2 ins. deep. The bolt holes are 1 × 1¼-ins., oblong, with rounded corners to prevent cracks. The bolts are ⅞-in. diameter, with T heads passing into the tie and held between ribs under the rail seat. An eccentric washer on the bolt allows for an adjustment of gage, and this is secured by the clamp which holds the rail base. Tie-plates are sometimes placed under the rails. The joint or shoulder ties are 2 ft. apart, and the in-

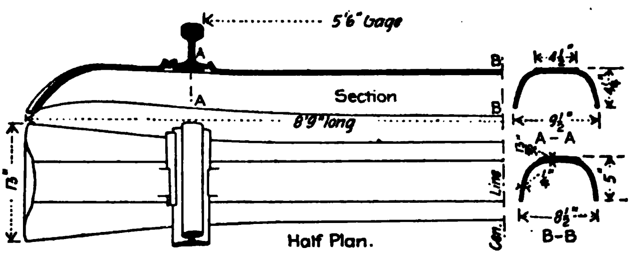


Fig. 24.—Rendel's Steel Tie; Indian State Railways.

termediate ties 3 ft. apart. The Post steel ties on the Gothard Ry., Switzerland, are 8 ft. 10 ins. long, 15-32-in. thick (at rail seat), and weigh 163 lbs. Allowing for the value of old material, these ties are actually cheaper in first cost than oak ties costing $1.20, and in tunnels the life is about the same, or 8 to 10 years. Even if they were less economical than wood, the steel ties would still be used on account of the greater security of the track on the heavy grades and sharp curves of this mountain road, with its heavy engines and traffic. (Engineering News, April 7 and Aug. 25, 1898). The Rendel steel tie, shown in Fig. 24, is extensively used in India, South America and Mexico for lines of 5 ft. 6 ins., 4 ft. 8½ ins. and 3 ft. 3⅜ ins. gage. For the widest gage it is 9 ft. long, 4½ ins. wide on top, 8½ to 13 ins. wide on the bottom and 4¼ to 5 ins. deep. The thickness is 13-32-in. on top and ¼-in. on the sides. Two lugs are stamped up at each rail seat, and a flat taper key is driven between the rail base and each of the lugs. The tie weighs about 135 lbs., and the keys 1 lb. each. The ties are usually laid about 3 ft. c. to c.

In this country the most extensive trials with steel ties have been made on the New York Central Ry. In 1889 there were 800 of the Hartford ties laid in stone ballast near Garrison's. They were so successful, and the cost of maintenance was so low, that a few years later a number of pressed steel ties of modified form were made, having a bolted clamp fastening devised by Mr. Katte, then Chief Engineer. These ties are shown in Fig. 25. They

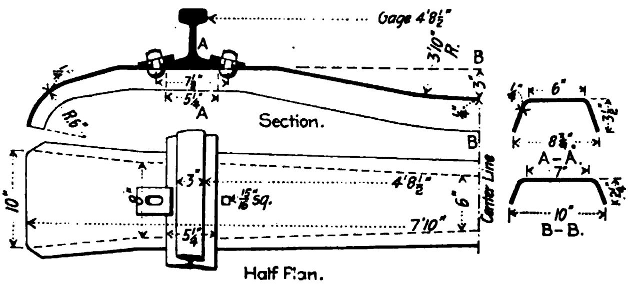


Fig. 25.—Steel Tie of New York Central Ry.

weighed, however, only 86 lbs., or 100 lbs. with fastenings, which was too light for such heavy traffic as they had to carry. According to reports made at the end of 1899, there were 721 of the original ties in 1,576 ft. of track, and while they were durable, they required nearly twice as much work to keep them in surface as was required for the adjacent track with wooden ties. They were also hard to line, the ballast shook away from them, and they made a noisy track. About 1,350 of the modified ties were then in use in 3,375 ft. of track, but were being replaced with oak ties. They were less satisfactory than the original ties, their shape preventing the economical lining of track, while they broke more readily in the middle and crushed under the rail. The quality of the steel, already referred to, was probably not suitable for the purpose.

The Standard steel tie (Fig. 26) has been tried on four or five railways, but the last were taken out in 1898. It was of channel section, placed with

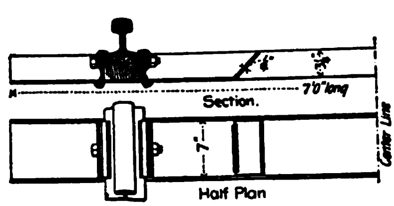


Fig. 26.—Standard Steel Tie.

the open side up, and having wooden blocks (with grain vertical) to which the rails were secured by clamps held by horizontal bolts through the blocks. The tie was filled with ballast, and the bottom was bent up at the middle to offer resistance to lateral motion, the ends being open. The weight was about 90 lbs. The Pennsylvania Ry. has tried some English steel ties. The Huntington & Broad Top Mountain Ry. is now trying the

Chester steel tie. This has two inverted trough rail-bearers, 12 ins. long, with stamped lugs to hold the inside of the rail base, the troughs being set parallel with the rails. They are connected by a tie-bar of inverted T-section passing through the sides of the troughs and having the top of its web notched to hold the outer edge of the rail base. The trough is slipped inward along the bar until the rail can engage with the notch on the bar, and is then forced out until its lugs hold the rail, when the ballast is tightly packed around it. No other means of fastening is provided. The troughs weigh 25 lbs. each, and the tie-bar 20 lbs. or 70 lbs. for the tie complete. A concrete tie in which a transverse steel truss is embedded has been tried on the Pennsylvania Lines near Chicago. With the exception of the New York Central Ry., however, all these experiments, while well enough in themselves, have been on too limited a scale to give results of any practical value.

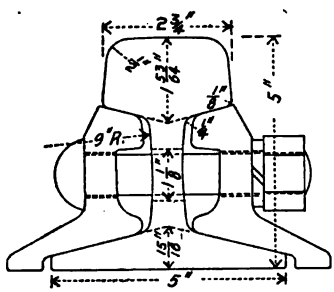
CHAPTER 5.—RAILS.

The T-rail or flange rail, which is now in common use all over the world, was invented in this country in 1830 by Col. Robert L. Stevens, Chief Engineer of the Camden & Amboy Ry., and the first order was placed in England by him for this road. He also designed the hook-headed spike and flat splice bar, which have developed into the modern spike, fish plate and angle bar. In Europe this rail is generally called the Vignoles rail, having been re-invented in England in 1836 by Mr. Charles B. Vignoles. The fish-plate joint was also re-invented in England by Mr. W. Bridges Adams, in 1847.

When railway development was recommenced in 1865, after the close of the Civil War, more attention began to be paid to the design of rails, and in 1865 Mr. Ashbel Welch designed a T-rail whose proportions approximated to those of modern sections, but whose head was rounded in accordance with the English practice of that day. About 1874, Mr. R. H. Sayre designed a rail having a head with top corners of large radius and sides sloping outward from the top, with the idea of reducing the wear caused by the wheel flanges. The Sayre 76-lb. rail adopted on the Lehigh Valley Ry. in 1883 had a flare of 10°, but in the 80-lb. rail, adopted in 1891, the flare was reduced to 5°, which was retained in the 90-lb. rail of 1895 (Fig. 27). Mr. J. A. Milholland, President and General Manager of the George's Valley & Cumberland Ry., has advocated a section carrying the Sayre design to extremes, having a flare of 20°. This is based on the form of wear of 72-lb. rails on the sharp and frequent curves, but no such rails have been made. This is almost the last advocate of this form of rail head, the typical Sayre section being now almost entirely abandoned. It is now generally recognized that the best results are obtained with sharp top corners and vertical sides to the heads, as noted further on, though some designers still adhere to a slight flare of 4° to 5°, with the idea of keeping the wheel flanges away from the corner of the rail head. The Providence & Worcester Ry. rail of 1885 had the sides sloped inward from the top, a design which is decidedly bad. Between 1880 and 1888 there was a tendency to give the rail head a large top corner radius of ¾ to ⅞ in., to fit the fillet of the wheel tire. This, however, caused a considerable rubbing friction of the wheel flange on the rail head (aggravated

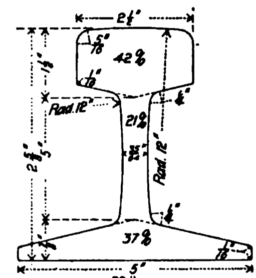
in some cases by outward flaring sides to the head), in addition to the normal rolling contact with the wheel tread.

In 1873 the American Society of Civil Engineers appointed a committee to report upon the form, size, manufacture, test, endurance and breakage of rails, and also upon the comparative economy of iron and steel rails. In 1883 another committee was appointed to consider the proper relations of



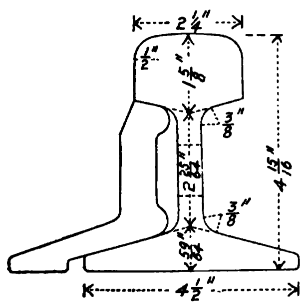
90 lbs.

Fig. 27.—Sayre Type; Lehigh Valley Ry.



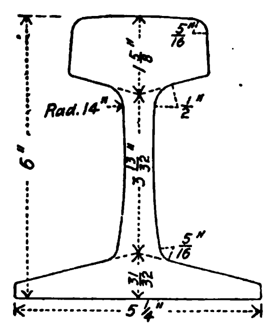
80 lbs.

Fig. 28.—Type of American Society of Civil Engineers.



72 lbs.

Fig. 29.—Sandberg Type.



100 lbs.

Fig. 30.—Dudley Type; New York Central Ry.

Rail Sections.

railway wheels and rails, in view of the disputed ideas as to these relations. It was asserted on the one hand that the rail head should have a round top corner and a head flaring outward from the top, to conform to the outline of the wheel fillet and flange. On the other hand, it was claimed that such a long line of contact would be dangerous (tending to cause derailment with sharp flanged wheels) and would cause undue wear and friction, and that therefore the rail head should have a sharp top corner and vertical sides in order to keep the wheel flange away from the rail head as long as possible. This committee's investigation showed the following: (1) That the number and disadvantages of sharp-flanged worn wheels had been greatly exaggerated; (2) that sharp corners did not produce this character of wheel wear to the extent claimed; (3) that round-cornered rails showed greater side wear due to cutting by the wheel flange, while the rail wear became

more rapid as soon as the side of the head began to be attacked; and (4) that rails often fail with little material abraded from the top by wear proper, being crushed after the flow of metal has reached its limit, and thus failing by rapid disintegration due to heavy wheel loads. The committee recommended a broad head relatively to depth, with a top radius of 12 ins., ¼-in. top corners, 1-16-in. bottom corners, and vertical sides starting from a sufficient base width to give ample bearing for the joint.

This led to the appointment of a third committee to prepare designs for standard rail sections, in an endeavor to reduce the number of existing sections (adopted at haphazard) to some standard of uniformity, so that rail mills would be able to roll to stock, instead of having to roll so many special sections. At that time there was an almost entire lack of uniformity in rail design, each engineer having his own ideas, and desiring to have his own special form of section on his own line. The rail mills therefore had to carry enormous stocks of rolls for all these sections, though many of the sections were practically identical, having minute variations as the result of the whim of the designer or his ignorance of the existence of a practically identical section. This committee made a very thorough investigation, and in 1893 presented its report (which was adopted), recommending standard sections, in which the metal was distributed as follows: Head, 42%; web, 21%; base, 37%. This is probably the best distribution yet made, provided that the rails are of good material, and thoroughly rolled, the rolling being as slow and finished as cold as practicable. This type of section is shown in Fig. 28. The sections vary by 5 lbs. from 40 to 120 lbs. per yd., and in all of them the height and width of base are equal, while the following dimensions are constant:

	Radius.		Radius.
Top of head	12 ins.	Side of web	12 ins.
Top corners of head	5/16-in.	Top fillets of web	¼-in.
Bottom corners of head	1/16-in.	Bottom fillets of web	¼-in.
Corners of base	1/16-in.	Fishing angles	13°

Within the past few years these sections have been very extensively adopted, and there is at the present time a general approval of what are commonly termed the "Am. Soc. C. E." sections, as well as a strong tendency towards the use of uniform standard sections. The advantages are felt by the makers as well as the users of these rails, for not only does their general adoption reduce the idle capital invested in a large stock of rolls and enable the mills to roll rails for stock, but experience shows that rails of the Am. Soc. C. E. section can be rolled at a lower temperature and require less cambering than sections having a greater proportion of the metal in the heads. There are also fewer "wasters" or "seconds" from rails rolled to these sections, and the sharp corners have no material effect upon the life of the rolls. It will be noticed that the third committee adopted 5-16-in. as the radius of the top corner, instead of ¼-in., as recommended by the second committee. This was partly to effect a compromise with the advocates of a round corner, and partly to make the section more generally applicable on curves. The section was designed particularly for the tangents and easy curves which compose by far the greater part of the railway system, so that some modifications may be made to give more satisfactory results on lines having a large percentage of very sharp curves. Such modifications have been made in a few instances, as in the Manning rail noted

below, but as a matter of fact the Am. Soc. C. E. section is used with success on many lines of this character, and additional sections are not desirable. An investigation made by the author in 1900 showed that out of 50 leading railways (representing 120,000 miles of road), 35 railways (with 75% of this mileage) had adopted this form of section as standard, and were using it in all renewals. The same investigation showed that no excessive wheel wear has been caused by the sharp cornered rails, except that on one road it is believed that at rail joints the corners (on new rails) act as chisels to cut the tires unless the rails are in perfect alinement. This effect disappears after a time. A similar effect appears when a stretch of track is laid with new rails or rails of a new section (especially if they have a wider head), to which the worn wheel tires do not conform. The relation of wheels to rails and frogs is discussed in Chapter 7.

As to the form of section, then, it may be said that the concensus of experience and investigation is that the head should be broad and relatively thin, with sharp top corners of ¼ in. or 5-16 in., sides vertical, or nearly vertical, and having fishing angles of not less than 13°. The flatter the under side of the head can be made, without affecting the rolling, the better, and the top and bottom fishing angles should be the same. In England the angle is usually 20 to 30°. The web is made with either vertical or curved sides. The latter design gives no greater strength, but is claimed to give a better compression of the metal in the thick parts at the union of the web with the head and base. Flat-topped rail heads have been advocated, but the metal in the head would not get so much work or compression from the rolls, and would thus be of less dense texture on the wearing surface than is desirable. This was found with rails rolled in England some 30 years ago for the New Orleans & Chattanooga Ry. In addition to this, the lateral play of the wheels would soon wear the top to a curved outline. The usual top radius is 12 or 14 ins. The Chicago, Milwaukee & St. Paul Ry. makes it 18 ins. for its 75-lb. rails, but for its latest 85-lb. rails has adopted the Am. Soc. C. E. section, with 12 ins. radius. The Pennsylvania Ry. has adopted 10 ins., and Mr. Sandberg has adopted 6 ins., but any radius less than 12 ins. is objectionable. The edges of the base should not be too thin, and should be vertical, with 1-16-in. top and bottom curves, the latter reducing the cutting of the ties by the sharp edges. The width of base should be equal to, but not greater than, the height of the rail, and if metal tie-plates are to be used the width of base may be slightly less.

Increasing the width of base has little effect in reducing the cutting of ties, which is due to the motion more than to the direct pressure of the rail, while the metal in the extra width of base between the ties is practically useless. Metal tie-plates will reduce the cutting much more effectually and will allow the metal in the rail to be distributed to the best advantage. The attempt to get a very wide rail base usually results in a bad section for rolling. Some of the older rails had a deep and heavy head combined with a wide thin base, and in order to roll the flanges while hot the rails had to be finished when the metal in the head was so hot that it could not be properly compacted and hardened in rolling. Mr. Sandberg, the European rail expert, favors heavy rails, but in his latest sections he has increased the width of rail base so as to avoid the use of tie-plates, for while he advocates their use, he has found it difficult to get them introduced by European rail-

ways. The rail section has suffered in consequence, and even with oak ties (and almost certainly with softer ties) the rails will still cut under heavy traffic and wheel loads. When the traffic will justify a very heavy rail, it will be more economical to provide tie-plates liberally than to adopt a wide-based rail. The reasons for the disfavor with which tie-plates are regarded in Europe are probably their size and weight and cost, and the difficulty of securing flat plates firmly to the ties, so as to prevent rattling. The American type of light self-attaching tie-plates is unknown in Europe, as already noted. Sandberg's rails have wide, round-cornered heads; and his 72-lb. rail (Fig. 29) was formerly the standard on the Canadian Pacific Ry., but has been abandoned for an 80-lb. rail of the Am. Soc. C. E. standard. His present form of 100-lb. rail is 5¾ ins. high, and 6¼ ins. wide, with a head 3 ins. wide, having a top radius of 6 ins. and ⅛-in. top corners. The proportion of width to height is bad, as already noted. He admits that sharp corners may be used with the short truck wheel base of American cars, instead of the long rigid truck wheel base of European cars, but it may be doubted whether this distinction is of much importance. It may be mentioned that some of the so-called Sandberg "Goliath" rails are modified from the original to a section for which Mr. Sandberg disclaims responsibility.

The rapid increase in weight of locomotives, cars and train loads has led to the use of heavier and stiffer rails in the sense of girders to carry the increased loads, but in many cases without correspondingly wider heads to sustain the increased wheel pressure ratios per square inch of surface contact between rails and wheels. As a result, in some such cases, the metal of both rails and ties has been overtaxed, excessive wear and flow taking place, and neither wheels or rails giving as good service as had been expected. Broad, well worked heads are required for the best efficiency of both rails and wheels. With this in view and as the result of the inspection of some 25,000 miles of track with his dynagraph car, Mr. P. H. Dudley designed a set of rail sections to meet the conditions of service thus ascertained. This type is shown by the 100-lb. rail of the New York Central Ry., in Fig. 30. It will be noticed that the fillets are of large radius, and that the narrowest part of the web is above the center line. This gives extra resistance to twisting, so that the head will not bend over the web, nor the web over the base. The first of these was designed in 1883 for the New York Central Ry. The following is from a statement by Mr. Dudley:

"The static pressures under passenger car wheels on rail heads 2¼ to 2⅝ ins. wide, range from 30,000 to 100,000 lbs. per sq. in., while those of locomotive driving wheels range from 110,000 to 150,000 lbs. To sustain such wheel pressures without undue flow and wear, requires not only broad heads, but a high grade of metal in the rails. Comparisons of tire records on the New York Central Ry. before and after the use of the Dudley 80-lb. rail (5⅛-ins. high, 5 ins. width of base, 2 21-32-ins. width of head and 5-16-in. corners of head) show that with an increase of 40% in weight per driving wheel the mileage per 1-16-in. of wear per tire is about the same for the heavier locomotives on the 80-lb. rails, as formerly for the lighter locomotives on the 65-lb. rails. The former carried 20,000 to 23,000 lbs. per wheel, and averaged 19,300 miles per 1-16-in. wear of tire. The latter carried 13,360 lbs. per wheel, and averaged 19,400 miles per 1-16-in. wear. Since the general use of this 80-lb. rail, the locomotives rarely go to the shop to have the driving wheel tires turned unless other repairs are needed, the wear of the tires no longer determining when the engines must go to the shop, as was the case when running on the 65-lb. rails. The mileage

before returning the tires is from 150,000 to 190,000 miles. These facts show the value of the broad heads in increasing the life of tires as well as of rails."

The relation of good heavy rails to economy in operation is shown by experiments in which hauling a train load of 378 tons at a speed of 55 miles per hour required 820 HP. on 65-lb. rails, and 720 HP. on 80-lb. rails, while it was estimated that only 620 HP. would have been required on 105-lb. rails.

In Table No. 5 are given the dimensions of a number of modern standard rail sections. The first four show the comparative designs of four principal types of sections. The "American Society of Civil Engineers" and Dudley types are undoubtedly the best, the latter being somewhat the stiffer and being designed for use with tie-plates, hence the narrower base. The Sayre, Sandberg and Pennsylvania Ry. types are defective in the roundness and heaviness of their heads, and in their lack of height.

The advantages of heavy rails for tracks carrying heavy loads and heavy traffic, and the increased efficiency and economy due to the use of such rails, are now widely recognized, as shown by the very extensive adoption of heavier rails which has been noticeable for the past few years. The increase in weight, however, is still lagging behind the increase in traffic and wheel loads. Besides being heavy enough to properly sustain the traffic, the rails must be heavy enough to have a margin of safety to provide against the exigencies of badly tamped or widely spaced ties, the heaving of the roadbed in winter, and the effects of flat or eccentric wheels. Stiffness is as important as weight in rails under heavy and fast trains, and this is one of the principal reasons for an increase in weight. It is also one reason why a reduction in weight of rail cannot properly be made for a closer spacing of ties or even with a continuous bearing for the rails. As the weight is increased, the fiber stresses in the rail decrease, as shown later on. Mere increase in weight does not necessarily insure improved service, but design and manufacture are both of great importance. In a rail having a large proportion of metal in the head, the metal will not be thoroughly rolled, and this coarse-grained or soft metal is more rapidly worn. As only a certain depth of surface wear can be allowed before the rail becomes unserviceable, the large head may really give no more wear than a smaller one, and such a rail may give even less wear than a lighter rail with a head so proportioned as to be rolled hard and dense. A good heavy rail, however, is a profitable investment, not only in point of service, but also in giving a stiffer and easier riding track. The heavier and stiffer rails give a better distribution of the stresses within the rail itself, and a better distribution of the load upon the ties and the roadbed, with considerably less dynamic effect. Having less deflection, they do not creep so much; they do not deflect so much at the joints, and the receiving ends do not cut out so much; while the rails do not "roll" so much, even without tie-plates, so that there is less work in maintaining the gage. Broad-top rails replacing narrower rails may show apparently excessive wear at first, owing to the wheels having been worn to the narrower head, and this insufficient bearing may also cause the wheels to slip. The train resistance of freight trains of 25 to 30 cars (600 to 700 tons) on light rails at 18 miles per hour was 6 to 8 lbs. per ton; while with trains of 80 cars (3,428 tons) on

TABLE No. 5.—DIMENSIONS OF RAIL SECTIONS.

	Railway and Type of Section.															
	C. & O. Ry. A. S. C. E.	N. Y. C. Ry. Dudley.	Penna. Ry. P. Ry.	Sandberg.	B. & A. Ry.	L. V. Ry. Sayre.	A. S. C. E.	Penna. Ry. P. Ry.	N. Y. C. Ry. Dudley.	Mich. C. Ry. A. S. C. E.	N. Y. C. Ry. Dudley.	Gt. Nor. Ry.	Sandberg.*	Ohio Cen. Ry. A. S. C. E.	N., C. & St. L.	C., B. & Q. Ry.
Weight, per yard .... lbs.	100	100	100	100	95	90	90	85	80	80	75	75	72	70	60	56
Height .... ins.	5 1/4	6	5 1/2	5 3/4	5 1/32	5	5 3/8	5	5 1/8	5	5	5	4 13/16	4 5/8	4 1/4	4 1/16
Width of base .... ins.	5 3/4	5 1/4	5 1/2	6 1/4	5 1/2	5	5 3/8	5	5	5	4 1/4	5	4 1/2	4 5/8	4 13/64	4 1/16
Width of head, top .... ins.	2 1/4	....	....	3	2 27/32	....	2 5/8	....	...	2 1/2	....	..	2 1/4	2 7/16	2 15/64	2 7/32
Width of head, bottom .... ins.	2 3/4	3	2 3/4	3	3	2 3/4	2 5/8	2 9/16	2 21/32	2 1/2	2 5/8	2 19/64	2 1/4	2 7/16	2 21/64	2 7/32
Side of head, slope .... degree	Vert.	4	4	Vert.	4	5	Vert.	4	4	Vert.	4	Vert.	Vert.	Vert.	...	Vert.
Depth of head .... ins.	1 45/64	1 5/8	2	1 7/8	1 9/16	1 53/64	1 49/64	1 11/16	1 1/2	1 1/2	1 3/8	1 11/16	1 5/8	1 1/32	1 55/128	1 43/64
Height of web .... ins.	3 5/64	3 13/32	2 9/16	....	2 15/32	2 41/64	2 35/64	2 7/16	2 1/4	2 5/8	2 3/4	2 1/2	2 29/64	2 15/32	2 7/64	2 1/4
Depth of base .... ins.	31/32	31/32	13/16	....	1	13/16	59/64	7/8	7/8	7/8	7/8	13/16	59/64	13/16	91/128	47/64
Thickness of web .... ins.	9/16	15/32	9/16	17/32	5/8	5/8	9/16	9/16	17/32	35/64	17/32	9/16	1/2	33/64	45/64	19/32
Thickness of edge of base .... ins.	5/16	5/16	3/8	3/8	5/16	3/8	1/4	5/16	1/4	1/4	9/32	..	...	1/4	1/8	....
Height to center of bolt hole .... ins.	....	....	2 7/32	....	2 9/32	2 1/16	....	2 1/32	2 1/4	....	2 1/8	2 1/16	2 11/128	...	1 19/64	....
Radius, top of head .... ins.	12	14	10	5 3/4	14	12	12	10	14	12	14	10	6	12	10	12
" top corner of head .... ins.	5/16	5/16	7/16	1/2	5/16	1/2	5/16	7/16	1/4	5/16	1/4	5/8	1/2	5/16	7/16	1/4
" bottom corner of head .... ins.	1/16	1/16	1/8	Shr'p	1/8	1/8	1/16	1/8	1/16	1/16	1/16	1/8	Sh'rp	1/16	3/16	1/8
" top fillets .... ins.	1/4	1/2	1/4	....	1/2	1/4	1/4	1/4	1/2	1/4	1/2	1/4	3/8	1/4	1/4	3/8
" bottom fillets .... ins.	1/4	5/16	1/4	....	5/16	1/4	1/4	1/4	5/16	1/4	5/16	1/4	3/8	1/4	1/4	3/8
" corners of base .... ins.	1/16	1/16	3/16	....	1/16	1/16	1/16	5/32	1/16	1/16	1/16		1/8	1/16	1/8	1/16
" sides of web .... ins.	12	14	8	Vert.	14	9	12	8	14	12	14	12	Vert.	12	8	11
Edge of base rd. or vert	Vert.	Vert.	Rd.	Vert.	Vert.	Vert.	Vert.	Rd.	Vert.	Vert.	Vert.	Rd.	Vert.	Vert.	Rd.	Vert.
Fishing angles of head .... degree	13	14	13	20	14	14	13	13	14	13	14	14	15	13	13	13
" " of base .... degree	13	14	13	20	14	14	13	13	14	13	14	14	15	13	13	13
Metal in head .... per cent.	42	40.8	49.0	46	..	47.8	42	....	42.2	42	41	44	37.6	42	48	41.8
" in web .... per cent.	21	23.5	18.5	17	...	18.2	21	....	21.1	21	23	22	18.1	21	19	21.7
" in base .... per cent.	37	35.7	32.5	37	...	34.0	37	....	36.7	37	36	34	44.3	37	33	36.5

*The 72-lb. Sandberg rail was formerly the standard of the Canadian Pacific Ry., but has been abandoned in favor of the 100-lb. section of the Am. Soc. C. E. type.

Dudley 80-lb. 5⅛-in. rails at 20 miles per hour, it was only 3 lbs. per ton. These stiff heavy rails also reduce the work of maintenance and renewals from 20 to 50% and are especially valuable where maintenance work is heavy, as on steep grades, in tunnels, etc.

The heaviest rail yet laid on this continent is the 110-lb. rail of the Chignecto Ship Railway (Canada), 6¼ ins. high and wide, but this line has never been finished. Rails of 100 lbs. per yd. are in use on the busy divisions of several important lines, and also in such special locations as tunnels and terminal approaches. That of the New York Central Ry., (Fig. 30) was the first to be rolled in this country, and was first adopted for the four track line approaching the New York terminal, in order to reduce the difficulty and expense of maintenance and renewals on tracks so crowded with traffic and laid largely in tunnel and in open cut with retaining walls. The minimum weight economical in ordinary service is 65 lbs. With lighter rails under considerable traffic, the diminished life of rails and ties, the increased cost of material and labor for maintenance and renewals, and the occasional sums involved in repairs and damage suits after wrecks, more than balance the cost of rails of suitable weight which will make a better track. For ordinary freight and passenger traffic on roads with easy curves and grades, the weight should be 70 to 75 lbs.; while for extra heavy freight traffic or fast passenger traffic, or on lines with sharp curves and steep grades, the weight should be from 80 lbs. upwards, and rails of 80, 85, 90, 95 and 100 lbs. are in service on various roads. It may be pointed out that the rail is only one part of the track, and that improvements in ballast, ties, fastenings, joints, etc., are of equal importance in the construction and maintenance of a first-class track. The laying of rails should be carefully done, though this is frequently neglected to some extent. New rails carelessly laid on old ties, may be given a wavy surface or a permanent set due to careless handling or to uneven bearing surfaces. This cannot afterwards be remedied, and will materially reduce the benefits that should result from the new rails. The laying of heavier rails on ordinarily good track should reduce the work of maintenance and renewals. It has already been explained that the number of ties should not be reduced when heavier rails are introduced.

The ordinary length of rails is 30 ft., but rails 33 ft., 45 ft. and 60 ft. long are used to some extent. Several railways have adopted 33 ft. as the standard length, thus reducing the number of joints by 10%; the Lehigh Valley Ry. has a considerable mileage of 45-ft. rails, and 60-ft. rails are used at bridges, etc., as well as in ordinary track. There is sometimes difficulty in turning these long rails on the right of way. The Norfolk & Western Ry. has 85-lb., 60-ft. rails, which are not found particularly awkward to handle. A report on long rails was made by a committee of engineers to the General Managers' Association of Chicago in 1894, with the following conclusions: (1) There would at first be an additional cost for manufacture, and a greater proportion of second quality rails; (2) Renewals of single rails would be more troublesome and expensive; (3) Transportation would be more expensive; (4) Unloading from cars would require a greater number of men, though not a greater number per ton, and not more than are ordinarily available. The benefits were enumerated as follows: (1) Reduction in number of joints, with economy in

their first cost and maintenance; (2) Fewer accidents and breakages at joints; (3) Smoother riding track. The report recommended miter joints, with an angle of 55°, and an expansion spacing of $\frac{5}{8}$-in. at zero. Later experience has by no means sustained the recommendation of the miter joint, and the spacing is now sometimes a maximum of 5-16-in. for 60-ft., 80-lb. rails. Some rail mills do not approve of the long rails, claiming that they are difficult to straighten, but this is largely a matter of mechanical skill and is by no means an insuperable objection. In point of fact, a considerable proportion of the ordinary 30-ft. rails require to be straightened before being put in the track. The cost of maintenance is about the same with rails of any length.

Continuous rails, with the ends welded together in the track, are extensively used on street railways, and are being tried (but with bolted or riveted joints) in railway track. With this arrangement no expansion spacing is given. In 1893, Mr. Torrey, Chief Engineer of the Michigan Central Ry., laid six stretches of continuous rails, 800 ft., 500 ft., 250 ft. and 100 ft. in length, forming 1,000 ft. of track. The rails were laid end to end, and the rails and splice bars were then drilled for 1-in. turned bolts, switch points being used to allow for expansion at the ends of the lengths. The 800 ft. length was afterwards reduced to 500 ft., on account of excessive expansion, but the track is said to be giving very satisfactory service. In June, 1889, the "self-surfacing" continuous track invented by Mr. P. Noonan (1886) was laid for 3 miles on the Durham Division of the Norfolk & Western Ry. The 56-lb. rails were laid on ties buried in the earth, and the spike heads were left $\frac{3}{8}$-in. clear above the rail base, so that the wave motion of the rails could not affect the spikes or ties. The motion of trains was said to be as easy as on heavy rails and stone ballast. Close joints were made with $\frac{3}{4}$-in. rivets, but at the ends of the section were switch points to allow for the total expansion. The track was turfed over, and 3-in. drain tiles were inserted to carry the water out beyond the track, but the ties decayed more quickly by being buried. The new track was not lined or surfaced for 18 months, the only maintenance expense being for a watchman, though 50-ton engines ran over it at high speeds. During the same period, the labor expense for maintenance of the adjoining three-mile section was $1,890. Eventually the track got out of line and surface, being laid in wet clay cuts and on banks which settled, and when the ties were renewed, in 1895 or 1896, the ordinary style of track construction was followed.

Steel rails were first rolled in England about 1855, and in the United States experimentally in 1865, and to order in 1867, when the improvement of the Bessemer process of 1862 (largely due to and introduced in this country by Mr. A. L. Holley), led to greatly increased facility of manufacture and a decrease in cost. This process (with Holley's improvements) and the consequent introduction of steel rails at moderate prices, were great factors in the enormous railway development of this country, and iron rails are now practically obsolete. As steel is homogeneous, the failure of rails in service is not by splitting and lamination, as in iron rails, but by (1) normal wear or abrasion of the head, (2) cutting out and bending at the joints, due to the blows of the wheels, (3) the flow of the metal of the head under

heavy wheel pressures, and (4) occasionally by fracture, steel rails being less liable to fracture in cold weather than iron rails.

In the manufacture of Bessemer steel rails, pig irons of the desired grade are melted in cupolas or the metal from the blast furnaces is poured into mixing tanks, the molten metal in either case being charged into the converters, a certain proportion of scrap being then added. Air at about 25 lbs. pressure is blown in from the bottom of the converter, and burns out the silicon and carbon. The proper degree of carbon is then added by a charge of spiegeleisen, and the molten steel is then poured into the casting ladle and thence into the ingot molds. The ingots are generally about 16 × 18 ins., 4½ ft. long, weighing about 5,000 lbs. After being taken from the molds, they are kept upright in a furnace called a soaking pit until needed. The ingot is first rolled in a blooming mill, which reduces it in section, making a bloom or bar about 8 ins. square and 24 ft. long. The bloom is then cropped at least 12 ins. at the ends, to cut off any spongy parts, and cut to length making from 1 to 4 rails according to weight. The bloom may then be reheated, or go direct to the rail mill. Here the roughing rolls give it the approximate shape, while the finishing rolls give it the required section and form the name of maker, date, weight of rail and other marks on the web of the rail. The rails are then cut to length by circular saws (usually 30 ft. 6½ ins., which will be 30 ft. when cold), then go to a cambering machine and then to the cooling beds, where the camber (6 to 12 ins. according to the distribution of metal in the section) is taken out in cooling. From the beds, the rails go to the straightening press, where the burr left by the saw is chipped off, the ends filed, and the rail hammered with a gag to take out horizontal kinks. The gag should not be applied to the rail head, and some better system of straightening is to be preferred, as the gag marks form places for wear to start, and the kinks sometimes reappear when the rails are laid. In fact, rails frequently require to be straightened again before being laid. The rails are then measured for length, drilled for the bolt holes and placed on the inspection or shipping beds.

One of the most important chemical components of rail steel is the carbon, the proportion of which ordinarily ranges about as follows, according to the views of individual designers or makers: 60-lb., 0.40 to 0.45%; 70-lb., 0.45 to 0.50%; 80-lb., 0.48 to 0.55 or even 0.60%. The maximum proportion is 0.65 to 0.70%, as specified for the 100-lb. rails of the New York Central Ry. The object of the high carbon proportion is to make the steel hard, but it is liable to render it brittle unless special care is taken in proportioning the other chemical components and in the process of manufacture. Under these conditions, however, a rail can be made combining hardness (to resist wear) with toughness (to resist fracture), and such rails have given most excellent results in service. The Boston & Albany Ry. has had the Dudley 95-lb. rails (with 0.6% carbon and 0.06% phosphorus) in service under heavy traffic since 1891, but out of 75,000 tons not one rail broke during the winter of 1892-3, although subjected to a minimum temperature of —30° F. The general experience in the United States is that the high carbon rails give a longer life and are not more liable to fracture, while they are much less subject to flow or deformation under heavy loads. In Europe, however, their manufacture has been less successful, and the rails have a decided tendency to fracture. Foreign mills also object to them on

account of the greater expense of manufacture. The idea was at one time advanced that soft or low-carbon steel would be best for rails, but a very little experience soon exploded this fallacy. Silicon makes the steel fluid and dense, producing solid ingots and fine crystallization. Manganese is required for chemical purposes during the blow in the converter, and gives a certain ductility in rolling, but tends to cause coarse crystallization in the rail and flow of the metal under traffic. Mr. Sandberg employs over 1% of manganese for hardness, and claims that greater strength and clean rolling result, but the carbon must be correspondingly reduced to make the rails stand the drop test. Sulphur and phosphorus are objectionable impurities, the former tending to make the metal seamy, and the latter tending to make it brittle. The chemical proportions for rails cannot be stated arbitrarily or uniformly, but the specifications must be prepared with regard to the quality of the ore to be used and the weight of the rail. The design and the methods of manufacture are as important as the chemical proportions. Some roads do not specify the chemical composition, but merely stipulate that the rails must pass certain tests. The Chicago & Northwestern Ry. and some other railways have no standard specifications for rails or splice bars, but the manufacture is subject to the inspection of some engineer or inspection bureau, guaranteeing that the material will meet the requirements laid down by the railway. This puts the matter in the hands of men making a special study of such work. Table No. 6 gives the chemical contents specified by some railway companies:

TABLE NO. 6.—CHEMICAL COMPOSITION OF RAILS.

Railways.	Weight of rail, lbs.	Percentage of Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
Boston & Albany	95	0.60 to 0.70	0.10 to 0.15	0.80 to 1.0	0.07*	0.06*
Buf., Roch. & Pittsburg	80	0.55 " 0.60	0.15 " 0.20	1.10 " 1.30	0.069	0.08
Chic., Bur. & Quincy	65	0.45	0.10†	....	....	0.085*
Chic., Bur. & Quincy	75	0.50	0.10†	....	....	0.085*
Illinois Central	70 to 75	0.45 to 0.55	0.10†	....	....	0.075*
Louisville & Nashville	70	0.47 " 0.57	0.15 to 0.20	....	0.07*	0.085*
Louisville & Nashville	80	0.53 " 0.65	0.15 " 0.20	....	0.07*	0.085*
New York Central	65	0.43 " 0.55	0.15 " 0.20	1.05 to 1.25	0.07*	0.085*
" "	70	0.47 " 0.57	0.15 " 0.20	1.05 " 1.25	0.07*	0.085*
" "	75	0.50 " 0.60	0.15 " 0.20	1.10 " 1.30	0.07*	0.085*
" "	80	0.55 " 0.65	0.15 " 0.20	1.10 " 1.30	0.07*	0.085*
" "	100	0.65 " 0.70	0.15 " 0.20	1.20 " 1.40	0.069	0.06
Norfolk & Western	85	0.53 " 0.63	0.10 " 0.14	0.9 " 1.10	0.04*	0.085*
Northern Pacific	72	0.50 " 0.60	0.10†	1.0*	0.05*	0.08*
Southern Pacific.‡	75 E.	0.48 " 0.58	0.10 to 0.15	0.8 to 1.0	0.07*	0.06*
" "	75 W.	0.45 " 0.55	0.10 " 0.15	0.8 " 1.0	0.05*	0.085*
" "	96 E.	0.58 " 0.68	0.10 " 0.15	0.8 " 1.0	0.07*	0.06*
" "	96 W.	0.55 " 0.65	0.10 " 0.15	0.8 " 1.0	0.05*	0.085*
Wabash	70	0.43 " 0.51	0.10	.....	....	0.085
"	75	0.45 " 0.53	0.10	.....	....	0.085
"	80	0.48 " 0.56	0.10	.....	....	0.085

*Maximum. †Minimum. ‡E = east and W = west of Alleghenies.

Basic open hearth steel rails have been tried on the Northern Pacific Ry. in order to get low phosphorus. These rails had 0.65 to 0.75% carbon, 0.65% manganese, 0.05% sulphur and 0.03% phosphorus. They showed but 50% of the wear sustained by rails having only 0.35% carbon, under the same traffic. Two 70-lb. Harveyized steel rails were laid on the Delaware, Lackawanna & Western Ry., and were removed after about 6 years service, as pieces began to break out of the head without showing any previous crack. The rails were 4½ ins. high, with 5 ins. base, and had worn down ¼-in. when removed. By this process additional carbon is absorbed by the head

after the rail is made, and analysis showed 0.76% for 1-16-in. depth of head, 0.42% at 2-16-in., and 0.3% at 3-16-in. About 50 tons of nickel steel rails were laid in November, 1897, in single track on the Cleveland & Pittsburg Ry., on a curve of 4½°, and after two years service showed less wear than the ordinary rails. In July, 1899, the Pennsylvania Ry. laid about 220 tons of 100-lb. nickel steel rails (of the Am. Soc. C. E. section) on the Horseshoe curve. In manufacture, the nickel caused red shortness to such an extent that the rolling of 300 tons resulted in only 220 tons of No. 1 and 57 tons of No. 2 rails, while 19 tons of the latter had to be rejected on account of "piping." The rails showed great rigidity under the straightening press, double the ordinary pressure being required for cold straightening, and the rails would often spring back, showing no effect from the blow. The steel was so hard that five twist drills were sometimes required in drilling one hole, and the best results were obtained by the use of Mushet steel drills without lubrication. The analyses of these nickel steel rails were as follows:

	Pennsylvania Ry.	Cleveland & Pittsburg Ry.
Carbon	0.504	0.53
Phosphorus	0.094	0.014
Manganese	1.000	0.800
Nickel	3.229	3.520
Silicon	.....	0.048
Sulphur	.....	0.021

After steel rails had come into general use, the specifications were often vague, and the supervision of manufacture and inspection of rails on behalf of the engineers and purchasers were not very close. The quality of the rails then naturally deteriorated, the makers turning out only such rails as would be accepted. Defective specifications and carelessness in manufacture account for the fact that many of the heavier modern rails were found to give less wear or service than lighter rails made when the manufacture was more carefully attended to. At one time engineers and rail makers even claimed that heavy rails could not be made which would give as good service as the smaller and lighter rails. This, of course, was entirely erroneous, but it is a fact that many of the heavier rails did not, and do not, give as good service as lighter rails. There is undoubtedly too great a tendency on the part of the makers to roll the rails too quickly and at too high a temperature, with the result that they are likely to be of inferior quality, due largely to their having been "squirted through the rolls" as the hot and rapid rolling has been termed. With the higher temperatures (2,000° or 2,200° instead of 1,400° or 1,600°), higher speed of the rolls (900 ft. per minute instead of 400 ft.), and fewer number of passes for the bloom (9 instead of 13 or 15), the modern steel rails cannot be expected to be of as good quality as those made under the opposite conditions. As the men are paid by the ton, they also have an interest in a large and rapid output, so that inspection is necessary as a check upon them. One of the highest records in rail rolling is that of the Illinois Steel Co.'s works, where in 1899 a day shift and a night shift made 1,301 and 1,310 tons of 60-lb. to 80-lb. rails in 12 hours each. The quality of such rails is at least open to question. Now that the chemistry and physical properties of rails are better understood, the specifications are drawn more strictly, but the makers are inclined to be arbitrary, having the matter now so largely in their own hands. In fact

some important railways have been unable to get the requirements of their specifications accepted or carried out, the rail makers preferring to follow their own ideas or to lose the contract. Under such conditions a high quality of product is not to be expected. Of course good rails are made, but as a rule they are not as good as they might or should be. In 1875, Mr. Ashbel Welch, chairman of the rail committee of the American Society of Civil Engineers, put the economical statement of the case as follows:

"An unwise saving of a dollar to the manufacturer, or a little unfaithfulness in the workman, will probably reduce the value of the rails $10 or $20. Ten or 15% added to the ordinary work on rails would double their value. An expert rail maker knows this very well, but he cannot put the $10 extra work on a ton in order that it may be worth $60 more to the purchaser, who will not allow him any part of the $10 out of the $60 he makes. The railway agent who purchases may also know all this, but he cannot follow his own judgment, for he knows his directors will say he paid $10 per ton more than the market price. It is thus that the interests of stockholders are sacrificed."

This put the responsibility on the purchasers who had been demanding "cheap" rails, but in later years, when the manufacturers (who now control the prices) put the price up to a high figure, the quality remained unsatisfactory in many respects, even when allowance is made for the increased wheel loads which modern rails have to sustain. The reason for this is that the high price is largely arbitrary, and does not represent increased care or expense in manufacture. In general, the rail mills have so much business that they practically dictate what the purchasers shall have, and are too busy to consider methods of improvement, but a more rational system is most desirable and will probably be established in time.

In 1889, Mr. Whittemore, Chief Engineer of the Chicago, Milwaukee & St. Paul Ry., stated that he had 65 to 70-lb. rails, which would carry less traffic than 56-lb. or 57 lb. rails made under the same specifications, which certainly seemed to indicate that as the mass of metal is increased more thorough working of the metal is required in the rolls. In one case, on that road, 8 miles of 67-lb. rails were removed in two years as no longer fit for service; while joining them, and carrying the same traffic, were 58-lb. rails which had been in use for 8 or 10 years and were still in good condition. On another road, 56-lb. rails laid in 1875 are still in service, while newer 80-lb. rails have a much greater proportion of breakages, and more rapid wear. Of late years, similar experiences have been somewhat general. The writer is strongly in favor of paying a good price for a good article, and experience has plainly shown that good rails bought at the price which they are really worth are far more economical than "cheap" rails bought at the low prices which have at times prevailed. On the other hand, many rails are very "dear" when their price and their quality are considered.

Rails should be rolled slowly for the final passes, and at a comparatively low temperature (1,400° to 1,600°) so as to give the metal a close texture and a smooth, hard, dense surface. The fineness of the grain in the steel is governed by the work applied to it as its heat decreases, while the wearing quality of the rails depends largely upon the closeness of the grain of the metal in the head. This is especially the case with high-carbon rails. A suggestion has been made that when the rails have received all but the

finishing passes, they should be set in a cooling chamber or passed along a hot-bed until they reach a uniform temperature low enough for the finishing passes. This would involve little additional delay or expense, as when once the chamber or the hot-bed was filled there would be a steady delivery to the finishing passes. It is usual to require all rails to be laid with the brand on the outside (or the inside) of the track, but there does not seem to be much importance in this, especially as it requires many rails to be turned. Both sides of the head are alike, except when bad or worn rolls are used, and such rails should be detected by inspection. Rails that are badly worn on one side, are often turned to give a new surface for wear, if the form is not distorted by the flow of the metal forming a "lip."

In some cases the manufacturer is required to guarantee a certain length of life, and to replace all broken or worn rails that have to be renewed within that limit. The New York Central Ry. and the Chicago, Burlington & Quincy Ry. furnish their own specifications and also require a 5-years' guarantee, which is embodied in the contract. This system is very generally followed in England, for rails for home and colonial railways, and is also adopted in European practice. It is generally recognized that the methods of manufacture should be left to a large extent to the discretion of the maker, the rails being carefully inspected and

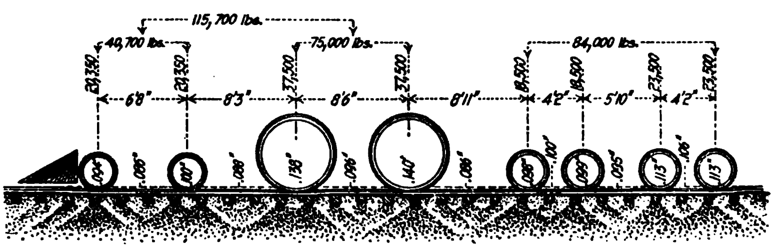


Fig. 31.—Track Deflections under Locomotive and Tender; Boston & Albany Ry.

tested on behalf of the purchaser to see that they meet the requirements of the specifications. Some roads, as already noted, have no standard specifications, but put the matter in the hands of inspecting engineers making this a specialty. Rail inspectors should be familiar with rail manufacture and with railway track practice. Test bars are sometimes made from the melted steel. Rails are usually tested by the drop test, with a weight of 2,000 lbs. falling 16 ft. for rails up to 70 lbs. per yd., and 20 to 24 ft. for heavier rails. The rail to be tested is placed with head or base upward, resting on supports 3 ft. or 4 ft. apart for the weights above noted. The rail must not break under one blow. The Dudley specifications for the New York Central Ry. require that in 90% of such tests, the rail butts must stand without breaking and must show at least 5% elongation in the inch which is subjected to the greatest tension. Other roads require only 3 to 4% elongation. Spaces of 1 in. marked on the rail under the point of impact enable the elongation to be readily determined. In calculating the weight of any section, the weight of the steel is usually taken as 10.20 lbs. for a 36-in. bar of 1 sq. in. For rails of 95 lbs. and over, however, 10.18 lbs. is found to give a closer result.

Stresses in Rails.—One of the most important advances in regard to determining the efficiency of rails, is the introduction of the stremmatograph, invented by Mr. P. H. Dudley, to determine and record the fiber stresses in rails under load, and the distribution of these stresses in the rails. This is a matter which is beyond mathematical analysis. As the load (static or dynamic) is applied, the rails deflect, and there is a compression of the ties, ballast and roadbed, the deflection and compression being naturally greatest under the wheels, or the points where the load is applied. Fig. 31 shows the total depression of track laid with 95-lb. rails and stone ballast, with a locomotive standing upon it. In regard to the rail under a moving load, there is a compression in the head, a tension in the base, and a shearing stress across the rail section at or near the ties which at that instant are bearing the load. The span of the rail deflection under the wheel is usually longer than the tie spacing. At a point a little distance on either side of the wheel the stresses are reversed, the head being in tension and the base in compression.* The tensile fiber stresses per sq. in. in rails of different weights (on stone ballast) under the driving wheels of a freight locomotive, with 113,800 lbs., and a passenger locomotive with 87,300 lbs. on these wheels, were as follows:

	Rails			
	60-lb.	70-lb.	85-lb.	100-lb.
Freight engine	16,050	11,510	10,030	9,430
Passenger engine	19,540	14,390	10,750	9,840

In a paper presented to the American Institute of Mining Engineers in 1899, Mr. Dudley gave complete records of the stresses in rails under and between the wheels of trains. A brief summary of a record for a train running at 20 miles an hour over 6-in. 100-lb. rails is given in Table No. 7, the stresses being measured on a 5-in. length of one rail.

TABLE NO. 7.—STRESSES IN RAILS.

	Tension, lbs.	Compression, lbs.
In front of first truck wheel	.....	2,362
Under first truck wheel	13,227	.....
Between truck wheels	.....	6,850
Under second truck wheel	7,086	.....
Between truck and driving wheels	.....	5,669
Under first driving wheel	8,267	.....
Between driving wheels	.....	7,086
Under second driving wheel	6,141	.....
Between engine and tender	.....	5,669
Under first tender wheel	4,960	.....
Between wheels	.....	2,834
Under second tender wheel	5,905	.....
Between wheels	.....	5,432
Under third tender wheel	4,448	.....
Between wheels	.....	3,307
Under fourth tender wheel	6,377	.....
Between tender and first car	.....	4,015
Under first wheel of rear car	7,322	.....
Between wheels	.....	3,071
Under second wheel of rear car	3,543	.....
Between wheels	.....	3,071
Under third wheel of rear car	4,017	.....
Behind third wheel	.....	1,417
Between trucks	.....	472
In front of fourth wheel	.....	945
Under fourth wheel	9,684	.....
Between wheels	.....	1,890
Under fifth wheel	7,795	.....
Between wheels	.....	2,834
Under sixth wheel	5,905	.....
Behind wheel	.....	709
Instrument returned to zero.		

*Engineering News, Oct. 6, 1898; Railroad Gazette, May 20 and Oct. 21, 1898; Feb. 23, 1900.

Wear of Rails.—The life of first-class 60 to 80-lb. steel rails on tangents is given in Wellington's "Economic Theory of Railway Location" (1887) as 150,000,000 to 200,000,000 tons. There are from 10 to 15 lbs. of metal, or ⅜-in. to ⅝-in. depth of head, available for wear, and abrasion takes place at the rate of about 1 lb. per 10,000,000 tons, or 1-16-in. per 14,000,000 to 15,000,000 tons of traffic. The rate of wear is increased locally about 75% by the use of sand by the locomotives. About half the metal in the rail head is available for wear, but this is not obtainable in main track, as the rails would be too rough for service; about ¼-in. to ⅜-in. is the limit of wear in main track, the rails being then removed to branch or side tracks (See "Curves"). The Dudley 100-lb. rails in the main tunnel approach to the Grand Central Station, New York (New York Central Ry.), had, in 1898, carried 75,000,000 tons with a loss of ⅛-in. The loss was greater at the north end of the tunnel, where the oxidization has always been very rapid. Many of the 100-lb. rails in the yards of this station carry 1,000,000 to 2,000,000 tons per month. The Sandberg 100-lb. rails in England, after seven years' service, had carried about 7,000,000 tons with a wear of 3-32-in. in the head, and he estimated the life at 30,000,000 tons. Mr. Price Williams, the English engineer, estimates 20,000,000 tons per 1-16-in. wear for bull-head rails, with a safe limit of wear of ⅜-in., or a life of 120,000,000 tons.

Modern rails fail more from deformation of section at or near the joints than from abrasion proper. The deformation and crushing are largely due to the driving wheel loads, the wear from which is estimated at 50 to 75% of the total. Heavy freight engines may have three or four driving wheel loads of 18,000 to 30,000 lbs. on a length of 12 to 16 ft. of the rail, while passenger locomotives have wheel loads of 16,000 to 25,000 lbs. The area of contact between the driving wheels and rails is an oval about ¾ × 1 in. (or 1 × 1⅛ ins. with worn tires or rails), with an area of 1.07 sq. in. The maintenance of rails ought not to exceed ½ ct., or 1 ct. per train mile, but it is very generally as much as 3 cts., owing partly to work on side tracks. In tunnels there is apt to be abnormal wear due to use of sand on damp rails, and also corrosion due to the effect of the dampness, the gases from the engine, and the drippings from coal, ore and refrigerator cars. Serious vertical and lateral bending of the rails, or even failure, are often caused by "dead" locomotives hauled rapidly in freight trains with the rods taken down; or by running engines with small wheels at excessive speeds. In both cases, the unbalanced forces due to the counterbalance weights in the driving wheels have a powerful and destructive effect upon the rails. The rails may also be injured by the slipping of driving wheels in carelessly starting trains at stations, water tanks, etc.

Expansion Spacing.—At the rail joints a space is left between the ends of the rails to provide for the expansion and contraction of the metal. If this is not done, or if the bolts are screwed up so tightly that the rails cannot slip in the splice bars, then in very hot weather the track may buckle to such an extent as to delay traffic or cause an accident. On a curve the line may be thrown out, so as not to be very noticeable, but on tangents the whole line, rails and ties together may be thrown out in a bow, or arched up from the ballast. The spacing is usually provided for in track laying

by using L-shaped shims or strips of iron, with the two legs of the different thicknesses required for spacing in warm and cold weather. The legs have the thickness marked upon them for convenience. Wooden spacing shims should never be allowed. The expansion of a steel rail 30 ft. long during a rise of temperature from —20° to +140° F. would be about 7-16 in. The coefficient of linear expansion of steel for 1° F. is given by Prof. Merriman in his "Mechanics of Materials" as 0.0000065. The expansion (in inches) of a 30-ft. rail for one degree increase in temperature would therefore be $0.0000065 \times 30 \times 12 = 0.00234$. In Table No. 8, compiled by Mr. W. C. Downing, Engineer of Maintenance of Way of the Vandalia Line, is given the variation in length of a 30-ft. rail for each 10° increase in temperature for a range of 160°, or from —30° F. to +130° F., the rails being assumed to be in contact at the latter temperature.

TABLE NO. 8.—EXPANSION OF STEEL RAILS.

Temperature.	Variation.		Thickness of exp. shim.	Temperature.	Variation.		Thickness of exp. shim.
— 30°	0.3744-in.	24/64-in.	6/16-in.	50°	0.1872-in.	12/64-in.	3/16-in.
— 20°	.3510-in.	23/64-in.	6/16-in.	60°	.1638-in.	10/64-in.	3/16-in.
— 10°	.3276-in.	21/64-in.	6/16-in.	70°	.1404-in.	9/64-in.	3/16-in.
0°	.3042-in.	19/64-in.	5/16-in.	80°	.1170-in.	7/64-in.	3/16-in.
10°	.2808-in.	18/64-in.	5/16-in.	90°	.0936-in.	6/64-in.	2/16-in.
20°	.2574-in.	16/64-in.	4/16-in.	100°	.0702-in.	5/64-in.	1/16-in.
30°	.2340-in.	15/64-in.	4/16-in.	110°	.0468-in.	3/64-in.	1/16-in.
40°	.2106-in.	14/64-in.	4/16-in.	120°	.0234-in	1/64-in.	1/16-in.
				130°	.0000-in.	....	....

There has been much discussion as to the expansion of 60-ft. rails and heavy rails. Where heavy rails reach the same temperature as lighter rails the expansion will be the same, but as the heavier rail takes a longer time to absorb the heat, and as the time of exposure to great heat is short, the practical result is that a smaller amount of expansion spacing is required. Long rails are usually of heavy sections. On the Illinois Central Ry., about half the theoretical expansion is allowed for heavy rails, and on this and some other roads the heavy rails are laid with close joints in warm weather. On the Chicago & Northwestern Ry., also, less expansion spacing is given with 80-lb. and 90-lb. rails than with lighter rails, as it is found by experience that the former expand less, even in hot summer weather. The Atchison, Topeka & Santa Fe Ry. specifies a spacing of ⅛-in. for hot summer weather, ¼-in. for moderately cool weather, and ⅜-in. for cold winter weather. The Louisville & Nashville Ry. specifies ¼-in. for extremely cold weather; 3-16-in. in spring, when rails are cold; ⅛-in. if lying in the sun and warm, 1-16 in. in hot weather, and close joints in the hottest weather. The Baltimore & Ohio Ry. specifies 1-16-in. for very warm weather, ⅛-in. during spring and autumn, and 5-16-in. during the coldest weather. The Illinois Central Ry. specifies 1-16-in. for the hottest weather, ⅛-in. during spring and autumn, and 3-16-in. for cold weather (all south of the Ohio River), and ¼-in. for the very coldest weather on the northern and western lines. In tracklaying, when there are great changes of temperature during the day, one set of shims should be used between about 9 a. m. and 4 p. m., and another thicker set of shims before and after these hours (see "Tracklaying"). On the New York Central Ry., no rails are to be laid with temperature below zero without instructions from the division engineer. The foremen must have thermometers. Continuous rails have already been referred to. The spac-

ings specified by railways in widely separated parts of the country are as follows:

TABLE NO. 9.—EXPANSION SPACING FOR RAILS.

N. Y. Central Ry.		Northern Pac. Ry.		Southern Pacific Ry.			Maine Central Ry.		Quebec Cent. Ry.	
Degs. Fahr.	Spacing.	Degs. Fahr.	Spacing.	Degrees Fahr.	Spacing.	M. M. dec. gage.	Degs. Fahr.	Spacing.	Degs. Fahr.	Spacing.
0	3/8-in.	0	5/16-in.	0 to 32	1/4-in.	0.250	30	1/4-in.	30 }	3/8-in.
20	5/16-in.	20	1/4-in.	32 " 50	7/32-in.	0.220	45	3/16-in.	40 }	
40	1/4-in.	40	3/16-in.	50 " 70	3/16-in.	0.200	60	1/8-in.	50	5/16-in.
60	3/16-in.	60	1/8-in.	70 " 90	9/64-in.	0.150	75	1/16-in.	60	1/4-in.
80	1/8-in.	80	1/16-in.	90 " 110	3/32-in.	0.095	90	0	70	3/16-in.
100	1/16-in.	100	0	110 " 130	3/64-in.	0.045			80	1/8-in.
				130 " 150	0	0.000				

Creeping.—In many places the rails develop a tendency to creep or travel along the track, both up and down grade, with and against the traffic. This is due to a combination of the effect of wave motion in the rails, unbalanced traffic in one direction, the action of braked wheels, the contraction and expansion incident to changes in temperature, etc. It is usually most troublesome with light rails on steep grades, bridges and swampy roadbed. The flanges of angle bars have slots in which the spikes are driven, but the narrow-flanged bars used on some roads do not give much hold for the spikes, which are therefore likely to be crowded out of the slots, leaving the rails

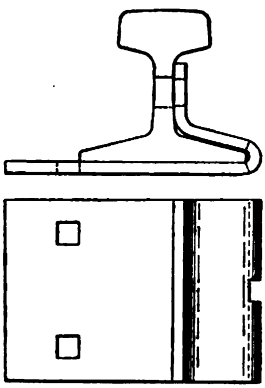


Fig. 32.—Check Plate or Creeper Plate; Boston & Albany Ry.

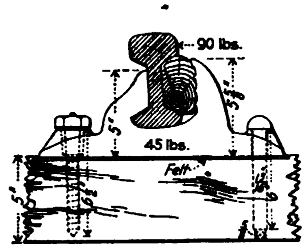


Fig. 33.—Bull-Head Rail and Cast-Iron Chair; London & Northwestern Ry. (England).

free to creep. Wide-flanged bars are the best, with slots about 7/8 in. deep, but bars having holes instead of slots are still better, as they cannot get away from the spikes. It is bad practice to slot the rail base for spikes. Heavy rails and substantial track usually give much less trouble than light rails, and any ordinary creeping can usually be avoided by the use of heavy rails and carefully spiked angle bars. Where special trouble is encountered, it is best to anchor each rail at the middle of its length by means of a creeper plate or check plate, as in this way the motion of each rail is independent and not cumulative. The combined tie-plate and check-plate used at the middle of each rail on the Boston & Albany Ry. is shown in Fig. 32. It is made at the company's shops from plates 5/8 × 6 ins., and the tie-plate portion is 6 × 7¼ ins. Each plate has a bolt through the rail, and is screwed

to the tie by three spikes. The Chicago, Burlington & Quincy Ry. uses two pieces of angle bar 5 ins. long, bolted to the middle of the rail and spiked to the tie. Similar plates, used singly or in pairs, are used to prevent creeping at grade crossings. The Bonzano device consists of a steel bar $\frac{5}{8} \times 2\frac{1}{4}$ ins., so twisted that the middle lies flat against the web of the rail, to which it is bolted (over one of the ties), while the ends rest upon and are spiked to the adjacent ties. The creeping of track (rails and ties together) occurs somtimes on swampy roadbed, owing to the wave motion under traffic. To resist this on a track used by consolidation engines with a weight of 120,000 lbs. on the driving wheels, the Minneapolis, St. Paul & Sault Ste. Marie Ry. used ties 10 and 12 ft. long, with angle bars spiked to two ties at the center of the rail to keep the rails from creeping on the ties.

Many curious instances of creeping are familiar to track men and engineers. In general, rails are allowed to creep on bridges, and the joints are not slot-spiked, so as to avoid throwing undesirable strains upon the structures. If the creeping is to be checked, blocking should be placed between the ties. In one case, however, the creeping under traffic in one direction on a trestle 400 ft. long caused the angle bars (unspiked) to catch the spikes on adjoining ties, and pulled the entire deck 8 ins. up a 1% grade. The abnormal creeping on the Eads arch bridge over the Mississippi River at St. Louis has been carefully observed for some years. The bridge is double-track, and has a rise of 5 ft. at the center of its length of 1,600 ft., and here the creeping is fairly proportional to the traffic. Upon the east approach viaduct of 2,500 ft., with a grade of 1.56%, it was excessive, until the steel trestle was reconstructed as a much more substantial structure. On the bridge proper, however, the flexibility of the arch ribs under traffic will always accentuate the influence of the elasticity of the track. The force is sufficient to fracture splice bars and $\frac{7}{8}$-in. bolts, and to drive a 70-lb. rail round a curve of $5\frac{3}{4}°$ and straighten it again on the tangent. Means are therefore provided to allow the rails to creep without injury to the track or to the structure, and as there are two double crossovers which must be maintained permanently in place, eight creeping places are established. Two switch points are placed in the track, and the main rails pass outside the switch rails, which are firmly anchored to steel plates on the ties and have guard rails on the inside with a flangeway of 2 ins. When a rail has nearly pulled past the switch points, another is coupled on, while a rail that has pushed through is uncoupled and taken back to the other end of the section. From November, 1899, to July, 1900, the creeping per month on the bridge proper was as follows, the maximum being in the summer, as a rule:

	North rail.	South rail.
Inbound track	9 ft. 2 ins. to 23 ft. 4 ins.	9 ft. 3 ins. to 26 ft. 3 ins.
Outbound track	9 ft. 3 ins. to 28 ft. 8 ins.	8 ft. 0 ins. to 42 ft. 3 ins.

Rails for Relaying.—In worn rails taken out of the track as no longer fit for service, the proportion of metal lost by wear is comparatively small, and the bulk of the rail becomes scrap. A process for re-rolling such rails, to form new rails of somewhat lighter weight, has been introduced by Mr. E. W. McKenna, and many railways have availed themselves of it. The burr or fin on the outside of the rail head is first ground off and the rail is then heated in a reverberatory furnace to a cherry red heat, or about 1,200° F., care being taken that the heat is not sufficient to affect the chemical

composition of the rail. The rails are then passed through two sets of rolls, which reduce them to a symmetrical section, while they derive some benefit from the extra working of the steel. The rails are, of course, elongated, so that often 30-ft. rails of the lighter section are made. They are then sawed, straightened and drilled in the usual way. Old 75-lb. rails, reduced to 73 lbs. by wear, have been rolled to form new 69-lb. rails. Many rails are taken out of main track on account of the bending and wear at the ends, and such rails may be made available for main track on branch lines by cutting off the ends and redrilling the rails. After the rails are cut they are calipered as to height and sorted in groups varying by 1-32-in., so as to form an even track. On the Michigan Central Ry., they are laid in lots of 80 upon a bed, and are numbered consecutively with chalk. A man with a box of slips or "dominoes" then calipers the height of each end of each rail, making the number and the heighis upon a slip. He then sorts out his slips, or "plays dominoes" with them until he has matched rail ends of the same height, usually matching about 60 rails. He then renumbers the slips in this order, and numbers the rails with paint in the same order. A loading machine then loads the rails on the car, taking No. 60 first, so that in unloading on the track No. 1 will be the first handled. In this way good rails and good joints are secured at low cost. The 20 rails which do not match well go over into the next lot. For sawing rails in this way, several roads use rail-sawing cars which are hauled to the various divisional points where the rails are collected. The car of the Chicago, St. Paul, Minneapolis & Omaha Ry. is 61 ft. long, with a framing of 20-in. steel I-beams. The equipment includes a 42-in. circular saw, straightening press, and two double rail drills, 34 ft. apart. The cars loaded with old rails are on one side of the machine, and the rails are handled by pneumatic goose-neck cranes, like ship's davits. Eight holes (two rails) can be drilled at one time, making the drilling capacity equal to the sawing capacity. In ordinary service, from 450 to 500 rails can be treated in a day of 10 hours. On the Michigan Central Ry. the cost of handling, sawing, drilling and matching the rails is about 75 cts. per ton, and the crop ends have a value as scrap (Engineering News, Dec. 7, 1899).

The Manning Rail.—In discussing the design of rails, at the beginning of this chapter, it was explained that the Am. Soc. C. E. section was specially designed for the tangents and easy curves which make up by far the greatest proportion of the railway system, although they are successfully used also on sharp curves. Mr. Manning, Consulting Engineer of the Baltimore & Ohio Ry., has devised a rail which is intended to have a longer life on curves. The form is in general similar to the Am. Soc. C. E. section, but its special feature is an unsymmetrical head, which feature was embodied in a rail section invented a few years ago by Dr. Vietor, of Germany. About 3-64-in. of metal is added to the top of the rail, and about ¼-in. in width is added to the gage side of the rail head. The top corner radius of 5-16-in. is retained, but the gage side of the head is vertical for only ¼-in. below this, being then curved inward on a radius of 1 in. The outer side of the head is vertical. The rail is designed in view of the following conditions: (1) The life of rail for main track use is limited to its initial wear (before being moved), and that wear cannot extend beyond the point where the wheel flange begins to cut the splice bar; (2) the rail is destroyed at a much

more rapid rate after the wheel flange has got a full bearing. The first of these conditions is provided for by the extra metal on the gage side of the head, and it is claimed that the metal between the curved line and a vertical line would not only be useless, but would provide a full flange bearing, allowing the rail to assume such a shape as would invite derailment from sharp flanges. Mr. Manning argues against the practice of turning rails, on the ground that the wheels do not get a proper bearing on such rails, owing partially to the formation of a lip along the top outer corner, and this is his main reason for the unsymmetrical head. It does not appear that actual experience bears out this reasoning (except in special cases), the unworn outer side being very generally in fair condition for use as the gage side. In the rail as first designed it was intended that the additional metal on the side of the head should present a vertical face, and that when this side of the head was worn nearly to the limit, the rail should be turned. The engineer or roadmaster would, of course, see that the rail was not allowed to wear such an extent as to make it unfit for service when turned. Renewals on account of side wear usually form but a small percentage of the total renewals, except on roads or divisions having considerable curvature and heavy traffic. It certainly seems most improbable that—except, perhaps, in a few special cases—this modification of the form of section will (as claimed) give the rail from 50 to 75% additional life in its initial position before it is consigned to less important work than main track. Neither does it seem probable that it will effect a saving of 37% per ton per year in cost of rail renewals, as claimed. Equally good results could probably be obtained by a broad-headed rail which could be turned when the gage side had sustained a reasonable amount of wear. In any case, a better quality of steel is now of much greater importance than any modification in design, and an increase in number of sections is undesirable.

Double-Head Rails.—In Europe the double-headed reversible rail, carried in cast-iron chairs, was early designed, but the indentation of the lower head by the chairs made the reversed rails very rough and liable to break. In 1858, the bull-head rail was introduced, having the lower head only large enough to give a seat in the chair and a hold for the wooden "key" or wedge which secures the rail in the chair. This is now the standard in England, and is used to some extent in European and other countries. The Pennsylvania Ry. has experimented with the 90-lb. bull-head rails of the London & Northwestern Ry. (Fig. 33), both on steel ties and wooden ties, but this track has not been able to stand the heavy traffic. One of the great objections to these rails is that they require two heavy cast-iron chairs (26 to 56 lbs. each) on every rail, merely to hold the rail up. These involve much useless material, and the wear at the chairs limits the life of the rails, being even more than the wear at the joints. Some of the rails have rounded heads, while others have vertical sides and sharper top corners. In England the erroneous idea very generally prevails that a T-rail track is necessarily unsafe, and this at one time even led to the use of double-head rails for colonial railways, involving much unnecessary expense which might have been applied to the construction of a greater mileage of the more suitable type of T-rail track now almost universally adopted. Mr. Freund, of the Eastern Ry. of France, proved that a T-rail secured to oak ties by screw spikes is as secure from lateral displacement as a bull-head rail in

chairs or a T-rail with tie-plates on pine ties. He further concluded that the T-rail gave better service, as the life of the bull-head rail is limited by the wear in the chair rather than that of the running surface. In most European countries, except England, T-rails are extensively used, but are often of poor design and too light for the traffic, especially with the wide spacing of ties, which is very common. The consequent poor results in service have caused this form of section to be regarded with some disfavor, European engineers, as a rule, not being well informed as to modern American track and its excellent service under conditions of fast, heavy and continual traffic. In some cases, a narrow-based T-rail has been adopted, carried in cast-iron chairs very similar to those for double-headed rails, and secured by large wooden keys, which make an objectionable fastening.

Compound Rails.—Various forms of compound rails have been designed to enable the wearing part of the rail to be renewed, but the majority have proved failures. This has been owing to faulty connections or too great complication, and consequent cost. In some cases the head was divided vertically, but in most designs the head was complete in itself, and detachable from the web or base. A flangeless T was a favorite form for the head, with the stem fitting into the grooved web of the base, or between two longitudinal angles. The cost of manufacture and of construction in the track would make such systems prohibitive even if mechanically successful. The small contact surfaces, however, would not suffice to resist the strains, especially those imposed by modern loads, and wear of rivets or bolts would soon result, with consequent rattling of the track. The worn material could only be sold as scrap, while worn rails are available for relaying, and command a higher price than scrap.

CHAPTER 6.—RAIL FASTENINGS AND RAIL JOINTS.

One of the weakest points of the track is in the fastening of the rails to the ties, for in spite of the increase in weight of rail, and the enormous increase in wheel loads, train loads, traffic and speed, the almost universal fastening is still the ordinary spike developed from Col. Stevens' hook-headed spike of 1830. This was an excellent device in its day, and is still suitable for light rails carrying light rolling stock and traffic, but it is unsatisfactory and uneconomical for first-class modern track, with 80 to 100-lb. rails, carrying heavy traffic and the great weights of modern locomotives and trains. The spike is simply a large nail, and depends solely upon the friction of the fibers of the wood for its hold in the tie. The ordinary rough spike is a disgrace to a main track, as it tears and crushes the fibers so barbarously that their hold upon it is comparatively slight. Improved spikes, with smooth sides and clean sharp edges and points, are being used to a considerable extent, and are much less injurious and more efficient, but the spike, in principle, is not a sufficient fastening for rails which carry heavy and fast trains. Even on good roads, with careful maintenance, loose spikes are common, being forced outward or pulled upward by the rail. Newly driven spikes in good ties have a tolerably good hold, but this is rapidly reduced by the constant vibration and working of the rail

under traffic, and by the "spike killing" of the tie by the continual working up and driving down of the spikes, which latter work is often an appreciable proportion of the work of maintenance.

The spike being held by friction only, the vertical wave motion of the rail under traffic gradually draws it out of the tie, while the lateral thrust on the rail by the wheel flanges (especially on curves) tends to tilt the rail outwards, drawing the inner spike up and pressing the outer spike back into the wood. This enlarges the spike holes, besides wearing and abrading the neck of the spike. The great advantages of the tie-plate in preventing the "necking" of the spikes have already been pointed out. Boring holes for the spikes would prevent much cracking and checking of the wood, and with holes of proper diameter, would increase the holding power and adhesion of the spikes. Comparatively little attention has been paid to the question of improved fastenings, although many forms have been designed and some have been tried experimentally, while the defects of the spike have very frequently been pointed out. It is most desirable for safety and for economy in maintenance, that some more efficient fastening than the spike should be generally adopted, but at the present time the maintenance of way department has, as a rule, only the spike to consider, and must make the best of it. For heavy track, a fastening should be adopted which will give a positive hold on the tie, and not merely the frictional hold of a spike.

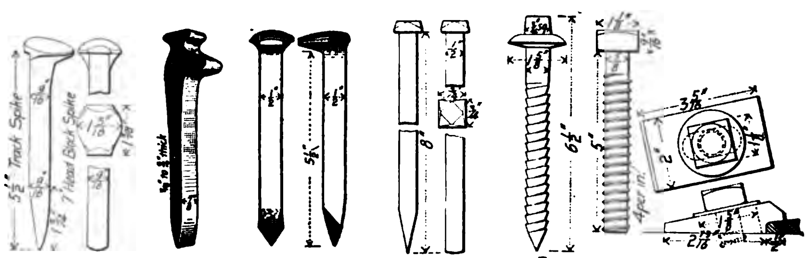

A. B. C. D. E. F.

Fig. 34.—Rail Fastenings; Spikes and Screws.

The common spike, as used on the Pennsylvania Ry., is of the form shown at A, Fig. 34. It is 5½ ins. long under the back of the head, 6 ins. long over all, 9-16-in. square, with the end wedge-shaped for about 1¾ ins., and terminating in a blunt chisel edge. The head is oval, about 1⅜ × 1 3-16 ins. The spikes weigh about ½ lb. and are put up in kegs of 200 lbs. A keg contains about 450 spikes ½ × 5 ins., 400 spikes 9-16 × 5 ins., or 375 spikes 9-16 × 5½ ins., the length being measured under the head. They have usually rough surfaces and blunt points, which crush and tear the fibers of the wood to a degree depending in part on the driving. A careful man can so drive a bad spike as to do comparatively little injury to the tie, while a good spike carelessly driven may cause considerable injury. A great improvement may be effected by the use of well-made spikes, having clean and even (not smooth) surfaces, sharp edges and sharp points, so that the fibers will not be torn, but will be cut by the sharp point and pressed back and downward by the body of the spike. The fibers thus tightly compressed, with their ends slightly bent down against the faces of the spike, offer a

strong resistance to pulling and tend to prevent the entrance of water. Various forms of spikes have been devised, but extensive experiments made at the St. Louis bridge and elsewhere have proved that it is by no means so easy to increase the holding power of a well-shaped and well-made common spike as might be supposed. Many patented forms have twisted, jagged or grooved surfaces, but attempts to increase the holding power by jagging the spikes have been mainly unsuccessful, as the projections tear the fibers unless they are small and so formed as only to press the fibers aside and allow them to spring back against the body of the spike. The head may be improved by making it larger and heavier than in the common spike. One form of head is much deeper than usual, but flush with the back of the spike, the top surface curving down to the rail and the head projecting farther than usual over the rail base. Spikes used on foreign railways, where they are sometimes used alternately with screws or bolts, have usually larger and heavier heads than the American spikes. Thus, some ⅝-in. spikes have heads 1 in. wide (lengthwise of the rail) and extending ⅝-in. over the rail base.

The Goldie steel spike (C, Fig. 34) is designed to injure the tie as little as possible. The end is ground to a sharp point, instead of to a chisel edge, while both edges and faces of the point are inclined so as to increase the cutting and wedging effect. The body is the same size all the way down to the point, and is made with clean surfaces and sharp edges. The Diamond and Crescent spikes have a bayonet groove in the back of the lower portion, the face being convex. The point is ground to a sharp edge, and is convex in the former (for cedar ties) and concave in the latter (for oak or knotty ties). The Greer spike (B, Fig. 34) is of varying section, 5½ ins. long, ⅞-in. wide and 5-16 to 9-16-in. thick. The swelling shape is claimed to increase the grip of the fibers, while the unusual width gives greater resistance to lateral thrust. Longer spikes are used for headblock chairs, as shown in Fig. 34, and for crossings. The crossing spike of the Pennsylvania Ry. (D, Fig. 34) is ½-in. square and 8 ins. long under the head, which is ¾-in. square. Boat spikes are better and cheaper than track spikes for fastening the planks of highway crossings, and the latter are too short for 4-in. planks. These boat spikes are usually ⅜-in. square and 7 ins. long. Where spikes are driven into longitudinal timbers, as in some cases on bridge floors, they are made with the chisel edge reversed, being at right angles to the rail so as to cut across the fibers of the wood, the same as in cross ties.

Numerous experiments made on the holding power of spikes show that there is a great variation, due to the kind and condition of the wood and the quality of the spike. As an average, a well-made 9-16-in. common spike, newly driven in a good oak or pine tie, may be assumed to have a resistance to pulling of 3,000 to 3,500 lbs. Resistances up to 7,000 lbs. have been recorded, but cannot be considered as obtaining in ordinary conditions of track and spiking. In inferior woods, the initial resistance may be only 800 to 1,800 lbs. The constant upward pull exerted by the rail under the influence of traffic very soon begins to lessen the resistance, and spikes redriven in their own or other old holes have a materially decreased holding power. Lag screws, or screw spikes, under ordinary conditions, may be assumed to give a resistance of 5,000 to 8,000 lbs. in oak, or 4,000 lbs.

in pine. This is maintained for a much longer time than with ordinary spikes.

Screw Spikes.—These have long been common in foreign practice, sometimes holding the rail direct by the spike head, and sometimes by means of a clamp, as in Figs. 21 and 22. They usually have a small projection or a number in relief formed on top, so that it will at once be evident if the spike has been driven home with a maul, this being strictly forbidden. On railway bridges, T-rails and bridge rails are often secured to longitudinal timbers by screw spikes placed against the rail base, or through holes in the base, the spikes being at such an angle that the heads have full bearing on the rail base. The holes are often drilled by crank augers, without the use of guides, and the spikes are screwed in by socket wrenches. In cross ties, the holes are often bored by machinery, but this is not always practicable, owing to the varying widths of rail base. The screw spikes of the Netherlands State Railways (Fig. 22) are 7.5 ins. long over all, 5.56 ins. under the head, 0.57-in. diameter in the shank and 0.89-in. over the threads, which have a pitch of 0.84-in. The mushroom head is 2 ins. diameter, with

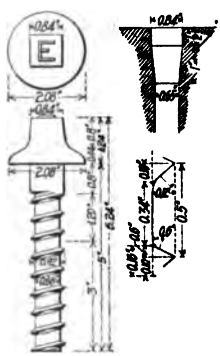


Fig. 35.—Screw Spike; Eastern Ry. (France.)

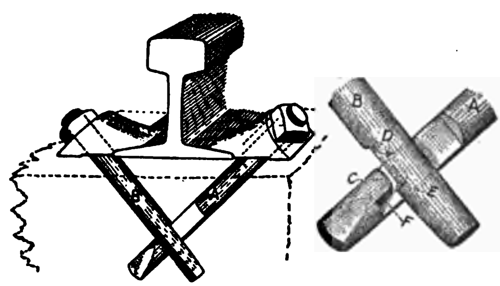


Fig. 36.—Bush Interlocking Bolts.

a tapering projection, 0.84 to 0.92-in. square, for the socket wrench. Fig. 35 shows the screw spike of the Eastern Ry. of France, and the form of hole bored for it.

In this country screw spikes have been but little used. The Southern Pacific Ry. has tried those shown at E, Fig. 34, in redwood ties, the holes being bored by machinery, but their use has been discontinued. The spike was ⅝-in. diameter, 5⅝ ins. long, with an inclined or ratchet thread, and was driven in a 7-16-in. hole. The Pennsylvania Ry. has tried screw spikes for fastening the 34-in. angle bars of 100-lb. rails to the joint ties. They were ⅝-in. diameter over the V thread, and 6½ ins. long under the head, which was ⅝-in. thick. They were put through holes in the angle bars, the uncut shank of the spike touching the edge of the rail base, and a cast washer giving a horizontal bearing to the head. They are not used now, as the parts were found to work loose very soon, which ought not to have been the case. On a very few roads screw spikes are sometimes used as rail fastenings on bridges.

A screw spike fastening devised by Mr. Katte, when Chief Engineer of the New York Central Ry., is shown at F, Fig. 31, and is in experimental use. The screw is of steel, with cold rolled threads having a pitch of 0.25 in. The clamp has a lip to bear upon the rail base, and a shoulder to receive the lateral thrust of the rail. The upper surface is approximately parallel with the slope of the rail base, while the lower surface is horizontal. A slotted hole permits of shifting the clamp ½-in. in order to provide for adjusting the gage without removing the screw. A thin steel washer prevents the edges of the spike head from catching in the edge of the slot. A ⅝-in. hole (the diameter of the body of the spike) is drilled in the tie with a hand auger. It is at right angles with the upper face of the clamp, a guide being used which consists of a vertical board with brackets at the bottom to enable it to stand, and having one edge cut to the desired slope of the spike hole. The bottom of the board is placed against the edge of the rail base and the exact position and slope of the holes are thus automatically fixed. It is reported that the screw heads broke off under traffic. One reason assigned for this is that the fastening was too rigid and that a flexible fastening is required to allow for the wave motion of rails. This explanation cannot be accepted, and is exactly the opposite of that given for the abandonment of screw spikes on the Pennsylvania Ry. Probably the screw spikes were not strong enough for their work. Rigid fastenings are needed, and screw spikes are so generally and successfully used in other countries that the failures of the above limited experiments have little significance. If efficient screw spike fastenings were in general use, the maintenance work of driving down and renewing spikes would be materially reduced.

Bolts.—Practically the only application of bolted clamp fastenings on wooden ties in this country is in the Bush interlocking bolts, Fig. 36, which are used to some extent on bridges and trestles, and sometimes at supported joints and on curves. The holes are bored with an auger at an angle of about 45°, intersecting under the rail, the proper position and angle of the holes being given by a guide clamped to the rail. Each bolt has a part of the shank cut away, and when driven home the bolts are turned so that they interlock, each bolt then pulling against the other. The clamps which bear upon the rail base have oval or slotted holes, so that the rails can be adjusted to gage and line. The bolt (A) is first driven, and then bolt (B). The nut of (A) is then screwed up until the shoulder (C) comes in contact with the shoulder (D) on bolt (B). The nut on (B) is then screwed up until the shoulder (E) bears against the shoulder (F) of bolt (A). To remove the fastenings, the nuts are taken off, and bolt (A) is driven down a little so that bolt (B) can be withdrawn. Bolt fastenings are quite generally used on bridges having solid steel floors. Usually there are two ordinary bolts, with rail clamps held by the nuts, but the Chicago, Milwaukee & St. Paul Ry. uses U bolts, with a saddle on the horizontal member, and a nut and clamp on each end. Such fastenings may be insulated by laying the rail on a strip of insulating material and placing washers of similar material between the rail and the clamps.

In foreign practice, fang bolts are largely used, the head bearing upon a clamp or directly upon the rail base, while the threaded end passes through a large nut under the tie. This nut has fangs or projections to bite into

the wood and prevent the nut from turning as the bolt is screwed down. In the author's paper on "The Improvement of Railway Track" (Transactions of the American Society of Civil Engineers, March. 1890) it was suggested that a better plan would be to have the head of the bolt underneath, using a fang washer with ribs to prevent the turning of the bolt as the nut is screwed on, as shown at (A) Fig. 21. A still simpler plan would be to have the fangs on the corners of the bolt head, which is quite practicable. Renewals of any through bolts are somewhat difficult, ballast having to be cleared away more or less, but such renewals are much less frequent than with spikes.

Rail Braces.—The lateral thrust on the rails at curves, turnouts, etc., is very severe, and the outer spikes are very generally reinforced by iron or steel rail braces, which are spiked to the tie and bear against the side of the rail, thus taking the outward thrust. Guard rails and the lead rails of turnouts are also reinforced by braces. Unless the braces are well designed and well looked after, their value will be very considerably reduced by the outer edge of the rail base cutting into the tie, the load being thus thrown on top of the brace and tending to raise its heel. To prevent this, a combination of tie-plate and rail-brace has been designed, one form of which resembles the box brace in Fig. 37, but has the sides cut away at the bot-

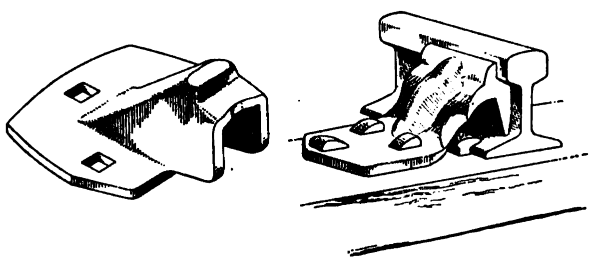


Fig. 37.—Rail Braces.

tom and the base plate extended in front for the rail to rest upon it. The box brace illustrated is of pressed steel, ¼ to 5-16-in. thick, and supports the rail head from below as well as at the side. The box fits over the rail spike. Another rail brace, of somewhat different design, is also shown. Steel braces are preferable to iron, as the latter are liable to be broken in spiking and are often made too light and not sufficiently accurate in shape to give good service. Almost any form of metal tie-plate will give increased safety and economy by preventing the cutting of the tie and the tilting of the rail, and such plates are now often used instead of rail braces. The ordinary braces do not prevent this cutting, so that the rail may be held by its head resting on the brace, thus displacing the brace so that it does not give proper lateral support.

The number of braces to each rail depends upon the sharpness of the curve. The Louisville & Nashville Ry. requires two braces on every fourth tie on curves of 4° and 5°, and on every third tie of curves of 6° and over. The Illinois Central Ry. specifies three braces to each rail on curves of 3° to 4°, four on curves of 4° to 5°, five on curves of 5° to 6°, and braces on alternate ties for curves over 8°. On the New York Central Ry., except

where tie-plates are used, there are four braces to each 30-ft. rail on curves of 3° to 6°, and six on all curves over 6°. The braces must be on the inside and outside rails, and placed on the same tie for both rails. Some roads specify three braces (at center and quarters) per rail on 5° curves with oak ties, and on 3° curves with cedar or other soft ties. Sometimes only the outer rail is braced, but generally the inner rail is also braced, so as to resist the thrust due to slow heavy trains, and also to relieve the outside spikes of the inner rail from the lateral pull of the tie due to wheel pressure against the outer rail. Guard rails at frogs should have two to four rail braces, according to length, unless these rails are clamped or bolted to the track rails.

Check Plates.—These plates are used to prevent creeping of the rails upon the ties, and have been described in the chapter on "Rails."

Rail Joints.

The rail joint has received very much more attention than the rail fastening, for while weak joints are perhaps no more dangerous than insecure fastenings, they cause a roughly riding track and a more apparent wear of the rails, the economical necessity of providing against which is more in evidence than that of the effects of inefficient fastenings. The joint is a troublesome part of the track, but much of the trouble with ordinary joints arises from the too general tendency to use cheap material. Whatever kind of joint is used, good results cannot be expected unless it is properly looked after. In fact a better track will probably be maintained where the section foreman is a little anxious about his joints, than where he has new joints which he considers can be left to take care of themselves. A good joint, well looked after, will require a minimum of expense and labor for maintenance. On many roads a considerable proportion of the maintenance work is expended in tightening bolts, raising low joints and other work at this part of the track.

The difficulty of making and maintaining an efficient joint will be understood if the work which it has to do is considered. It has to hold together, vertically and horizontally, the free ends of two independent rails which are subjected to very varying strains. At one extreme are the strains due to the hammer-like blows delivered by fast trains drawn by engines with driving wheel loads of 20,000 to 25,000 and even 30,000 lbs. per wheel, followed by a series of rapid blows from car wheels carrying 4,000 to 8,000 lbs. each. At the other extreme are the strains due to the pounding of slow heavy freight trains, drawn by engines having three or four driving wheel loads of 20,000 to 30,000 lbs., and followed by 120 to 200 car wheels with loads varying from 3,500 to 18,000 lbs. per wheel, aggravated perhaps by flat or worn wheels. For a perfect joint and a smooth riding track, the splicing must be such as to make the joint as strong and as stiff as the solid rail; and also as elastic, so that it will return to position after the depression or deflection caused by the loads, and thus carry the wave motion of the rail uniformly along the track. It should not, therefore, be more stiff or rigid than the rails to which it is applied. Very few joints have yet thoroughly met these requirements, and the effect of the loading is, therefore, to cause parts to become loose, and the rail ends to take a permanent set. If the joint and rail are of equal strength and flexibility, the wave motion will fol-

work of joint!

low on evenly with an unbroken curve. If the joint is the stronger or stiffer it will check the motion, while if it is the weaker then the rail ends will deflect so as to form a depression so sharp that the wheels cannot touch the extreme ends of the rails. In either of these latter cases the rails will become kinked and worn.

At each rail joint, when under load, there are two beams fixed at one end and loaded at the other, each carrying half the load. The deflection of these two beams is nearly ten times as great as that of the rail carrying the same total load at the middle and considered as a beam. The strength of the rail itself counts for little at the joints, and does not suffice to distribute the load over several adjacent ties, as it does at the middle of the rail. The joint ties therefore have to take practically the whole impact of the load, besides being subjected to a rocking or pumping motion. It is for this reason that these ties go down more than the others. The great wear of the rails at the joint is caused by the jumping of the wheels over the deflected rail ends, and not over the expansion spacing between the rails. This wear is greater just beyond the joint, in the direction of traffic, and on single track a greater depression of the rail surface may be found on each side of the joint than at the joint itself. Fig. 38 shows a rail joint plotted to an exaggerated scale for 2 ft. of each rail end. The upper line is for 80-lb. rails on gravel ballast, after 6 months service; the lower line is for older

wear at joint

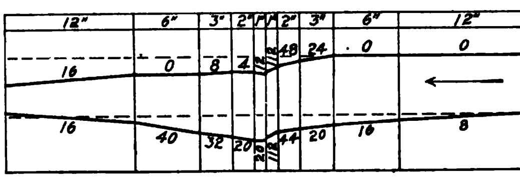


Fig. 38.—Diagram of Joint Deflections.

and lighter track. The end of the receiving rail tends to be permanently depressed, having a flatter up-grade to the normal level than the leaving rail. Investigation and experiment have shown that the wheel, in spite of the spring and the vertical play, has not time to follow the deflection of the rail ends, but jumps the depression (especially as the curves are convex) and strikes the receiving rail a few inches from the end, causing the rail to wear or cut out at that point. To this action is largely due the pounding, noise and wear at joints. With stiff and heavy rails, the deflection (with the consequent jump, noise and wear) is minimized. With lightly loaded wheels, stiff rails and heavy splices, the deflection will not be so great but that the wheels may touch the whole rail.

The drop at the gap left between the rail ends for expansion spacing will be almost imperceptible, for the versed sine of half the angle which has for its radius the radius of the wheel, and for its chord the width of the gap, is exceedingly small. With a 33-in. wheel and a ½-in. gap the drop of the wheel and axle would be only 0.002-in.; and only 0.008-in. with a gap of 1-in. The drop at a gap of ⅜-in. would be as follows: 30-in. wheel, 1-170-in.; 36-ins., 1-210-in.; 60 ins., 1-300-in.; 72 ins., 1-360-in. Experiments on the effect of the gap were made in Germany in 1892. On a side track in good condition, notches 0,12-in. deep and 0.6 to 1.2 ins. wide were cut in the rail

heads at points directly over the ties, where the rails could not deflect. Trial runs were made with a locomotive and inspection car, and the observers on the engine experienced noticeable shocks only in passing over the widest notches. Observers along the track could scarcely distinguish the special noise produced by passing wheels, and increase of speed seemed rather to diminish the noise and magnitude of the shocks. On the other hand, experiments of the same kind made on the Michigan Central Ry. showed considerable wear at the notches.

Miter Joints.—The idea that the gap for the expansion spacing caused the shock led to experiments with miter or bevel points as early as 1816 and 1824. In 1867, Mr. R. H. Sayre, Chief Engineer of the Lehigh Valley Ry., began experiments with rails cut at angles of 45° or 60°. This practice was followed from about 1869 to 1895 when it was finally abandoned, as many of the rails broke near the ends. The cracks usually started at the junction of the head and web, extending back about 3 ins. and then running up to the top of the head. The mitered rails on this road (76 and 80-lb.) have now been almost entirely removed. Such rails were also tried on the New York Elevated Ry., with Fisher joints, but were given up, and the miter joint is now practically obsolete. It is hardly possible that the miter cutting of the rails caused any appreciable benefit, as it does not in any way affect the yielding of the rail ends, which causes the shock.

Scarf Joint.—This old plan has been revived to a small extent within recent years, the rail ends being halved or scarfed, placed side by side and bolted together. As used on the Prussian State Rys., the rails are scarfed for 8½ ins., and have 26-in. splice bars with four bolts spaced 5, 4 and 5 ins., c. to c. The two middle bolts pass through both rails and both bars. In the ordinary form, the strength of the joint is diminished by the thin web, but Dr. Vietor, of Germany, has designed a rail with the head not set central over the web, so that only the head needs be planed away at the scarf, leaving both webs of full section. If this joint was put up like a riveted connection, or with tightly fitted bolts, it would be very stiff, but as the bolt holes must be large enough to admit of expansion, it is helped only by the friction of the webs, which depends upon the tightness of the bolts.

Splice Joint.—The flat splice bar or fish plate was invented in this country in 1830 by Col. R. L. Stevens, for the Camden & Amboy Ry., and it was reinvented in England in 1847 by Mr. W. Bridges Adams. With the early pear-shaped T-rail the deflection of the rail ends under load tended to force the plates apart and loosen the joint. With the modification of the rail section to practically its present form, with a high web and flat fishing angles, the joint became more practicable, and began to come into general use about 1855. This type of joint is now practically the standard throughout the world. It consists of two plates or bars, bearing against the underside of the rail head and the top of the rail base, and held together by bolts passing through the bars and webs of the two rails. In order to increase the strength, the angle bar was devised (first rolled about 1868 or 1870), having a vertical web like the fish plate and an inclined flange extending over the rail base. This flange adds to the lateral stiffness of the joint and keeps the track in better alinement. The angle bar joint is now almost universal in this country, and will probably continue to be the standard for the lighter

track. For first class heavy track, however, it will probably be supplemented by a base support to the rails, as noted below.

In some of the older joints, the outside bars extended along the side of the rail head, but this practice has been abandoned. The bars should be so designed and proportioned as to make the joint as strong and stiff as the body of the rail, in which particular many joints are defective, especially as to the stiffness to resist slight deflections. The bars are usually of uniform section throughout, but sometimes have the thickness of the web increased at the middle by tapering from the ends or by offsets, as in the Samson bar. The flange sometimes extends only about ½-in. beyond the rail base, or barely enough to give a hold for the slot spikes, as in (B) Fig. 39, which spikes may be crowded out of position by a creeping track. It is better to have wide flanges with deep slots for the spikes, and some roads have them wide enough for spike holes instead of slots, the spikes then re-

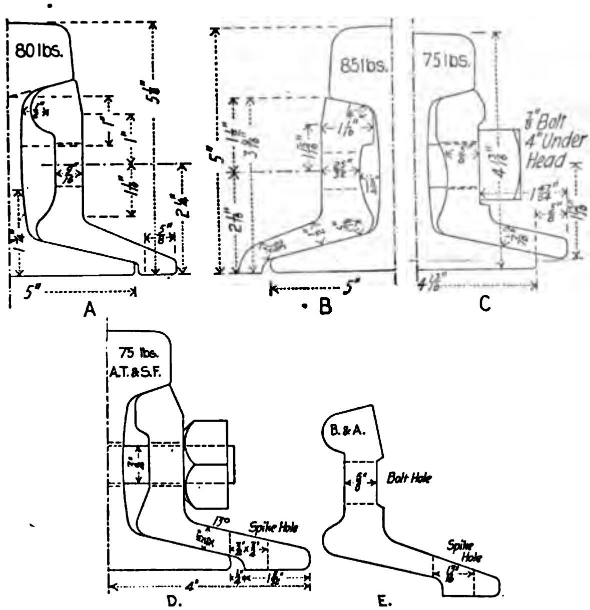


Fig. 39.—Sections of Splice Bars.

sisting motion in every direction and the gage being more permanently maintained. The base of the flange is usually brought down level with the bottom of the rail, so as to take a bearing on the tie, as in Figs. 27, 29 and 39. Many roads, however, keep the flange clear of the tie, as in Fig. 39 (C) and Fig. 41, but this practice is not to be recommended. The sections of splice bars vary very greatly, as shown in the illustrations, but one of the best is the Sayre section, shown in Fig. 27. The heavy top chord makes an exceptionally stiff bar, with wide bearing surface for the rail head. Fig. 39 (A) shows the Dudley design of bar of high-carbon steel for the 80-lb. rails of the New York Central Ry. The thick, narrow-flanged bar of the Pennsylvania Ry. is shown at (B), while (C) is the bar of the Chicago, Burling-

ton & Quincy Ry. At (D) and (E) are the heavily flanged bars of the Atchison, Topeka & Santa Fe Ry. and the Boston & Albany Ry., both having spike holes, and the latter being grooved to hold the bolt heads.

Splice bars are commonly made of steel which is far too soft for the purpose, having only about 0.1 to 0.15% carbon, or rarely 0.25%. Much better results would be obtained with steel having 0.3 to 0.4% carbon, and some foreign railways specify the same steel for rails and splice bars. In many cases a desire for increased strength is met by simply increasing the thickness of the web, coupled sometimes with an increase in the vertical thickness of the flange at its junction with the web. In the Dudley angle bar section, already referred to, the metal has been distributed with a special view to stiffness, the web being even thinner than usual, but the steel has 0.4% carbon, and is hard and tough to resist wear. The section is stiff, but has sufficient elasticity to make it give long service before taking a permanent set, and the web is thin enough to stand clean punching, without distortion or warping. The steel is required to have an ultimate tensile strength of 52,000 to 62,000 lbs. per sq. in.; elastic limit not less than half the ultimate strength; elongation, 25% in 8 ins.; and it must bend 180° flat on itself without fractures on the outside of the bent portion. The Michigan Central Ry. has laid several miles of track with splice bars of open-hearth steel having 0.65 to 0.7% carbon and 0.05 phosphorus. Under shop test they would stand a deflection of ¼-in. without permanent set. They have been very satisfactory in service on new rails, but will not hold up well on joints that have already deflected, which in fact few if any joint devices will do.

One of the bars usually has oval, square or kite shaped holes to fit a neck of corresponding shape on the bolt, thus preventing it from turning as the nut is screwed up. The other bar has round holes, which should be of such size as to require a smart tap on the bolt to send it home. If the bolts have L-heads bearing on the flange of the bar, or T-heads used with grooved bars (as in the Boston & Albany Ry. joint, Fig. 39), both bars may be punched or drilled alike. The holes in the rails are large enough to allow of contraction and expansion. On the Memphis bridge, the bolts have a driving fit in the holes of the splice bars, the holes in the rails being ¼-in. larger. In this way the two bars become practically one member, and good results have been reported. It is almost impossible to prevent thick bars from getting out of true if punched, and they should be straightened, as otherwise they will materially impair the efficiency of the joint. When splice bars are once notched or bent, the joint deteriorates rapidly, as it is almost impossible to restore the bars to proper line, though a straightening press for this work is used on some roads. To take up the wear at the top of the bar, right under the rail ends (which wear at once reduces the efficiency of the joint), a thin renewable bearing piece or liner may be set between the rail head and the bar, while some English railways use an iron washer at this point. It is obviously not economy to keep in service bent, worn, or crooked bars, as they lead to wear of the rails and general injury to the track.

In foreign practice it is very common to use bars of Z-section, having two vertical webs, the lower webs projecting below the rail and sometimes having bolts through them so as to cause the flanges to grip the rail base,

This form of bar is being introduced in this country by different designers, as in the Bonzano, Thomson and Churchill joints. The Bonzano joint, Fig. 40, has a pair of angle bars with flanges about 3 ins. wider than usual. The bars are heated, and the middle portion of the broad flange is pressed down vertically to project about 2¾ ins. below the base of the rail, thus giving additional stiffness. The bars are not cut or notched for bending, but the flat ends of the bars are punched with two spike holes in each. The section of the upper part of the bar is similar to that of the Sayre bars. The Thomson joint is somewhat similar, but the bottom webs are inclined inward at an angle of 45°, and extend 3¾ ins. below the base of the rail. These webs are only 7 ins. long, the ties being set about 22 ins. c. to c. The bars are 31 ins. long, with six bolts, and for 100-lb. rails they have an area of 6.97 sq. ins., with a weight of 85.40 lbs. per pair.

Breakage of Angle Bars.—The irregular manner in which splice bars fracture is due to the very varying conditions of load and support. The joint ties may be loose from the rails or loose from the ballast, and the transfer

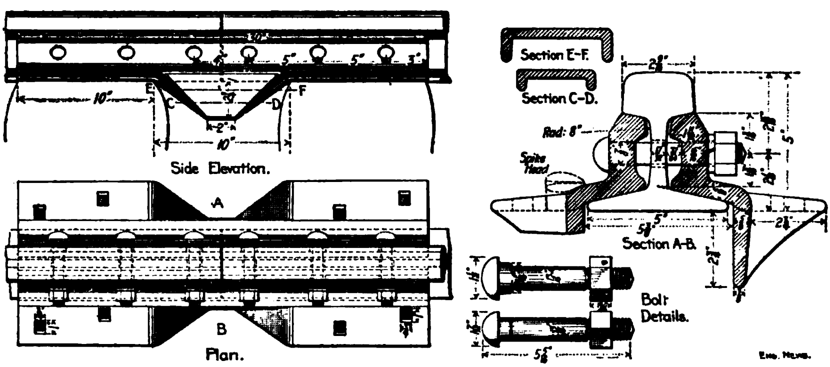


Fig. 40.—Bonzano Rail Joint; Pennsylvania Ry.

of the load from one rail to the other effects a reversion of strains in the angle bar at each wheel passage. Breaking of the angle bars from the bottom is often due to carelessness in raising track, the joints being raised too high before the centers or quarters are raised, instead of maintaining a proper surface in raising. With a wheel on each side of a supported joint, the tendency is to throw the joint up, the top of the bars being then in tension. With a suspended joint, the bars gradually get a deflection at the middle, and when the joint is raised, the tension strain is transferred from the bottom to the top of the bar. It has already been shown that the entering rail receives from each wheel a severe blow a few inches back from the end, which tends to loosen and drive down the shoulder tie of a suspended joint, unless it is kept well tamped. If this tie is allowed to become low in the ballast, the angle bars get a tension strain along the top as each wheel passes. If the tie is tamped up, and then allowed to get low again, the bars will eventually crack from the top. This may be prevented to some extent by lengthening the bars, though the ends of very long bars do but little effective work. Under normal conditions bars which fail

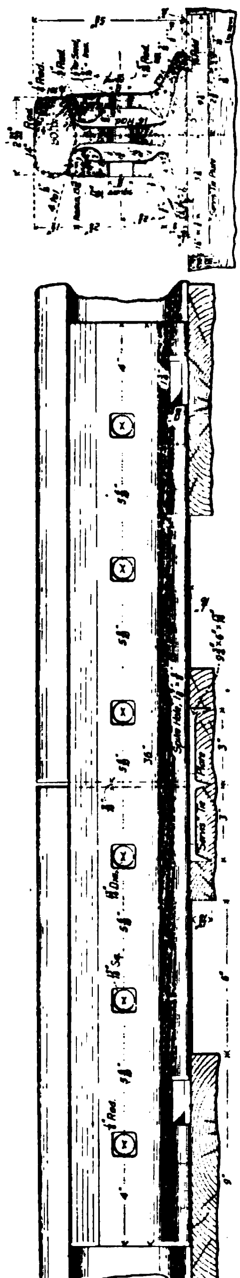


Fig. 41.—Three-Tie Rail Joint; New York Central Ry.

should crack from the bottom rather than from the top. (See paragraph on "Other Joint Devices," pp. 94, 95.) Broken angle bars should be replaced at once, and the track examined to ascertain the cause of the breakage.

Supported, Suspended, Bridge and Base Joints. —There are four general arrangements of joints: (1) Supported joints, with the rail ends resting on a joint tie; (2) Suspended joints, with the rail ends projecting beyond the shoulder ties and held only by the splice bars; (3) Bridge joints, in which the rail ends project beyond the shoulder ties but are carried by a bridge plate resting upon the ties; (4) Base joints, in which the bridge plate is replaced by a support under the rails which is bolted or clamped to them but does not rest upon the ties. The supported joint proper is now used to a comparatively small extent. It was found that with heavy wheel loads the joint tie did not give sufficient support. If tamped hard to prevent it from settling, it formed an anvil upon which the rail ends were battered, while the wave motion was not carried along uniformly and the track was likely to be rough. A modification of this arrangement, however, is the three-tie joint, in which two shoulder ties are placed close to the joint tie, and the angle bars are made long enough to extend over the three ties. This has been adopted by some important roads, including the New York Central Ry., and is considered to give good results under fast and heavy traffic. On the other hand, it is claimed that the three ties are too close together (6 to 8 ins.) to allow of proper tamping and that consequently one of three conditions will obtain: (1) The joint tie will be the more lightly tamped, making a suspended joint with a long span between the shoulder ties; (2) The shoulder ties will be the more lightly tamped, making a long and weak supported joint; (3) The third tie, or the shoulder tie of the entering rail, will be loosened by the jump of the wheels at the joint, and will thus cause the splice bars to be bent down, which with the reaction of the rail ends as the load is removed will cause them to crack from the top. Practical experience appears to show that these defects need not exist on well kept track. The suspended joint is by far the most generally used. It distributes the load over the two shoulder ties, and if the fastenings are properly designed it makes good provision for the deflection and wave motion. The

ties should be 8 to 10 ins. apart. Fig. 41 shows the three-tie joint of the New York Central Ry., and Fig. 42 shows the bridge joint of the Chicago & Northwestern Ry.

Bridge Joint.—This type of joint is coming more and more into favor, and is based on the most correct principles combining a base support with the necessary elasticity, if the bridge plate is not so heavy and stiff as to form an anvil. It is specially adapted for main tracks with heavy traffic. The rail ends should be so attached to the bridge plate as to be incapable of independent movement. Several forms of bridge joints are shown in Fig. 43. The Fisher joint, once well known but now very little used, has a slightly cambered bridge plate to which the rails are held by a transverse U bolt with clamps resting on the rail base and fitting against ribs on the sides of the plate. A curved steel spring plate between the plate and the horizontal leg of the bolt gives sufficient tension to prevent the nuts from slacking loose. To meet objections as to lack of lateral strength the clamps were made of angle form, with a vertical web long enough for two bolts, one through each rail, but those do not bear against the underside of the

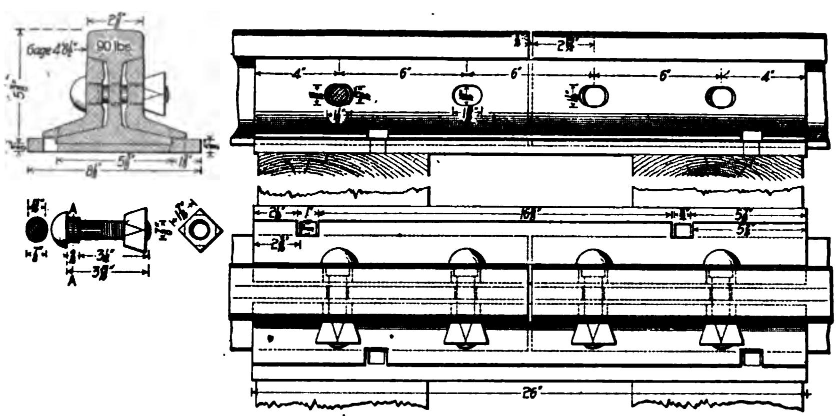
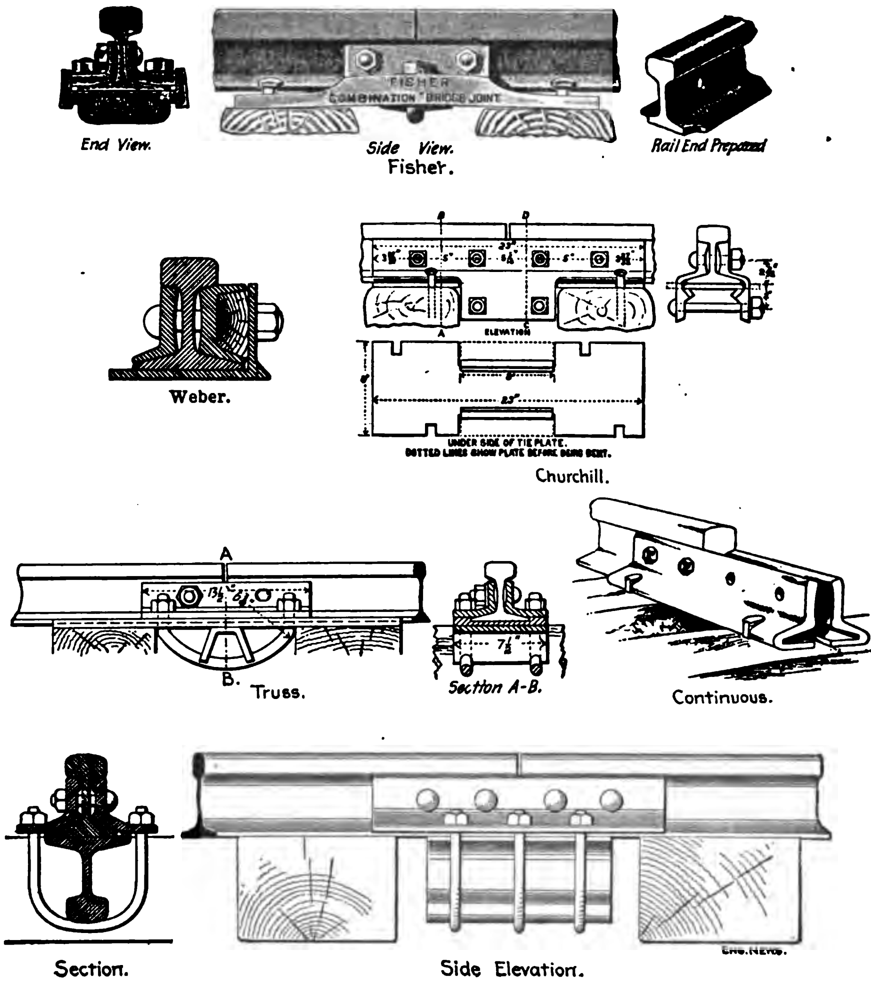


Fig. 42.—Bridge Rail Joint; Chicago & Northwestern Ry.

rail head, the inventor considering this unnecessary in connection with the base support. This idea is not approved by many engineers. The Churchill joint, used on the Norfolk & Western Ry., has a bridge plate 23 x 8 ins., 9-16-in. thick, with the sides bent down for 8 ins. at the middle to bear upon the ribs of the splice bars. These bars are 23 ins. long, with lower webs 8 ins. long, fitting the slots in the bridge plate. Two ¾-in. bolts pass through the lower webs, while four bolts hold the upper webs and rails together. The cost of maintenance is said to be only 50% of that where angle bars are used, while the track is in better condition. The Continuous joint has two angle bars with flanges bent round to fit under the rail base, but the bars must be of low carbon steel (0.1%) to stand the bending.

The Truss (or Long) joint, as used on the Chicago & Northwestern Ry., has a bridge plate 26 x 7¾ ins., with two long U bolts parallel with the rails, the nuts bearing on the wide flanges of the 13½-in, angle bars. These bars do not touch the rail head. A transverse bar of trough section is fitted



Torrey (Michigan Central Ry.).

Fig. 43.—Rail Joints of Bridge and Base Types.

between the bridge plate and the bolts. The Weber joint has an L shaped bridge plate, the web of which is on the outer side of the rail, with a channel splice bar and wooden filler between it and the web of the rail. A fish plate or angle bar is used on the inner side of the rail. The Heath or Common-Sense joint has a combined angle bar and bridge plate, with a fish plate on the opposite side of the rail. The bridge plate has a pocket stamped down at the middle to stiffen it, which necessitates the use of a low-carbon steel. The standard joint of the Chicago & Northwestern Ry., Fig. 42, has a grooved bridge plate 24 ins. long. but the rails are not bolted to it. A better design is the bridge joint introduced by Mr. Delano on the

Chicago, Burlington & Quincy Ry., in 1890, and still in use to some extent. The 12-in. angle bars (fitting the head and base of rail) were secured by two bolts to the rail and two bolts to the bridge plate, though four bolts through the rail would probably have been better. Some recent types of bridge joints have heavy malleable iron splice bars which extend under the rails and are grooved so as to receive and wedge upon the rail base. The bars are stiffened by ribs and may have projecting flanges to give an increased bearing on the ties. In the American joint, of this type, the bars have a dovetailed interlocking joint under the rails and no bolts are used, but lugs on the bars lock with studs fitted to the holes in the webs of the rails. This joint relies entirely upon wedge action. In the Atlas joint, the bars simply meet under the rail (as in the Continuous joint), and are secured by bolts through and under the rails. The Heath joint is now very little used, but the Continuous and Weber joints are extensively used.

Base Joint.—The most recent example of this type of joint is that designed by Mr. Torrey, Chief Engineer of the Michigan Central Ry., and is in somewhat extensive use on that road. It is shown in Fig. 43. Under the rails is an inverted piece of rail (or crop end) 10 or 11 ins. long, slightly cambered so that its ends are 1-16-in. clear below the base of the track rails. This is secured by three deep transverse U bolts, whose legs pass through the wide flanges of four-bolt angle bars. The flanges are horizontal, ½-in. thick, and do not touch the ties. A modification of the Fisher bridge joint is very similar to this, but has a shallow forging of T section in place of the inverted rail, while the splice bars bear on the ties and have only two bolts.

Other Joint Devices.—An early form of joint which has of late years been revived in Germany and tried experimentally on the Pennsylvania Lines has bolted outside of the rails a special piece of rail resting on the shoulder ties and having its head touching that of the track rails. This auxiliary rail is about 21½ ins. long, with its top level with the top of the track rail for 7 ins., and then inclined to the ends. The middle of the head must not be more than ⅞-in. wide, so as to clear the false flanges of worn wheels. A splice bar is used on the opposite side, and a filler splice may be put between the webs of the main and auxiliary rails, supporting their heads. The joint is said to be free from shock while the rails show little deflection or wear. The idea does not seem promising for permanent efficiency, as there will almost inevitably be a certain shock as the wheels strike and leave the auxiliary rail. As it is important that the ends of the rail heads should be held in the same horizontal plane, rising and falling together during deflection, a hinge joint would be ideal in some respects. A hinge joint is the standard type on the Indian Midland Ry., the joint being of the fish-plate type with five bolts. The middle bolt passes through notches in the ends of the rail webs, but the lack of fit between the bolt and the rail, and the small bearing upon the bolt, prevent this arrangement from having its full theoretical value. Hinged and dovetailed joints with interlocking rail ends have been devised, but the expense of shaping the ends makes their use impracticable. The number of patented joints is legion, but the majority are entirely impracticable. Of those which have been tried experimentally, many have been found to be inferior to a good angle bar joint. The in-

vestigation of the merits of these trial joints is a difficult matter, as in many cases they are put on with new rails or when the track is surfaced, and are assembled with special care. Any good results are then attributed to the efficiency of the joint, when they are really due to the improved track and the greater care in putting up the joints. A good angle bar joint, put up with equal care and under the same conditions would perhaps show even better results than the experimental devices. One road in particular has tried a large number of patent joints, but without satisfactory results, and in no case has the benefit been commensurate with the increase in cost. Many special forms of joint appear subject to a common weakness, in that insufficient or no provision is made against upward deflection of the rail ends caused by the application of the wheel loads between the first and second ties. This, as shown by the Dudley dynagraph records (Chapter 21), causes an upward deflection of the joint, followed by the better known downward deflection while the wheel is passing over the joint, and a second upward deflection after the wheel has passed the first tie beyond the joint. The standard angle bar in common use provides an extra thickness of metal on the upper edge as the practical outcome of experience, but the necessity for this appears to be overlooked in many special designs of joints. The series of deflections above noted may be provided for by thorough tamping of the ties next to the joint ties.

Insulated Joints.—Where rails have to be electrically insulated at the ends of block signal sections, etc., special forms of joints are required. The Neafie joint has a long channel-shaped base plate with a layer of insulating material upon which the rail ends rest. Long and heavy wooden splice bars are wedged between the webs of the rails and the sides of the base plate, and secured by six bolts. A block of wood or vulcanized fiber, of the same section as the rail, is fitted between the ends of the rails. The Weber joint is similar to the track joint already described, but has an L-shaped strip of insulating material against the bridge plate, and two heavy wooden splice bars.

Step Joints.—Where rails of different section meet, either on the main track, or where sidings have lighter rails than the main line turnouts, the smaller one is often blocked up to the proper height and the splice bars are bent to fit both webs, but this is not a satisfactory arrangement for first class track. On several lines the Atlas malleable-iron step joint is used for the purpose. This joint has two heavy side bars, projecting below the rail and having grooves made to fit the rail bases, which they grip tightly. Bolts are put through and under the rails. Mr. Sandberg has introduced cast steel "step" splice bars, while on the Chinese Imperial Rys. Mr. Kinder has used cast steel rails 27 ins. long, having half the length conforming to a 60-lb. and the other half to an 85-lb. section. These are secured to the rails by the ordinary splice bars. A somewhat similar joint has been devised by Mr. W. G. Curtis of the Southern Pacific Ry., but made from a piece of the heavier rail, 7½ to 30 ft. long. The outer side of the head is planed away gradually to fit the smaller rail, and the bottom is forged and formed to conform to this rail about 12 ins., beyond which the change to the heavier section is made in 15 ins. A reinforcing plate is riveted to each side of the rail so as to but against the splice bars of the lighter rail.

Expansion Joints.—With continuous rails, expansion joints must be provided at intervals to allow for creeping, and these are usually made with switch points. On long steel bridges and viaducts, some special joint must be used to allow for the expansion and contraction of the structure, and Fig. 44 shows the form used on the Poughkeepsie bridge, which provides for several inches of movement. A heavy base plate and upper packing plates form a trough in which the rail ends slide, the rails being "halved" for a length of 12 ins. Neither rail has its web cut. On the gage side of the rail the line is made perfect by planing off from the inside of the head an amount equal to the thickness of the web, the rail being slightly bent beyond the joint so as to permit this. The other rail is left of its original thickness. From the outside of one rail and the inside of the other ⅛-in. of metal is planed off, so as to make the rails enter truly at the joint, although their webs are 15-16-in. out of line. The axis of the joint is therefore ¼-in. from the axis of the rails on each side of the joint. The full width of rail head is 2 13-16 ins. The thin end of the left rail is 15-16-in. wide. All the sharp ends are rounded, but instead of the long outside taper

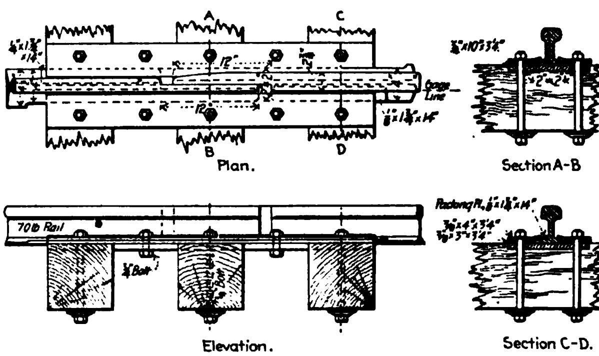


Fig. 44.—Expansion Rail Joint; Poughkeepsie Bridge.

of the right rail, it would have been better to bend down the top, leaving the full width. A double-flanged worn wheel would not then tend to crowd the wheel over and cause derailment, which is likely to occur with any kind of horizontal bevel such as shown in the figure. The rounding on the gage side, however, is highly desirable.

Drawbridge Joints.—At the ends of drawbridges special movable joints must be provided in order to allow of the rails bridging the gap between the abutment and the end of the bridge. In some cases the end rails on the bridge are about 10 ft. long, pivoted at the heel, and projecting so as to take a bearing on the abutment tie or sill, this being fitted with channel shaped rest plates having flaring sides which guide the rail into its proper position in alinement with the fixed rail. When the bridge is to be swung, the pivoted rails are raised clear of the rest plates by mechanism operated from the locking gear. Sometimes a piece of rail is bolted outside the pivoted rail, and projecting beyond it, to carry wheel treads over the gap. With lift or bascule bridges, the rails need not be pivoted, but the meeting ends of the fixed and bridge rails may be cut vertically at an angle.

Broken and Even Joints.—The rails may be laid with joints opposite one another, or with the joints on one side opposite the middle of the rails on the other side. Both methods are followed, but the latter is by far the most general practice. Even joints are used sometimes on new lines not fully ballasted, on account of the banks settling, it being claimed that the track rides easier, has less lateral motion and can be maintained better under these conditions. They are used mainly in the west, as with the comparatively light roadbed construction the track settles most at the joints. With broken joints, according to their opponents, the number of low places would be increased, and the weight of the train would be thrown against low joints, tending to throw the track out of line. With even joints, only the shock due to settlement will be experienced, and there will be less trouble in maintaining line and surface. On the other hand, even joints tend to form kinks in the track, and on many western roads, with comparatively light track, it is considered that broken joints make easier riding track, less liable to get out of line and less expensive to maintain. With broken joints, the hammering effect which tends to cause low joints is better distributed over the track (particularly when it is well ballasted), and there is less difficulty in keeping up the joints. The cars also ride more smoothly, as occasional low joints cause only a slight rocking of the car to one side, while low square joints would cause a more noticeable and unpleasant pitching motion. The rail ends also get more severely battered with square joints. At broken joints on double track with creeping rails, the ties may be slewed out of square, but the creeping should be and generally can be, stopped, in which case the objection disappears. Tracklaying takes more time with square joints than with broken joints, while with the latter the joints can run some distance ahead of the middle of the opposite rail (on curves) before it becomes necessary to cut a rail. In fact, some roads using square joint on tangents, use broken joints on curves. The opinions in favor of square joints, above noted, are by no means generally held, even in the west, and the prevailing opinions are strongly in favor of broken joints for all kinds of track, as they make a better running track, hold the surface and line better, and require less maintenance work. This latter point is an important one on a road with light track and a limited track force.

Length of Bars and Spacing of Bolts.—There is a very little uniformity in these details of track construction, but there is a decided tendency towards the use of short bars and closely spaced bolts, as may be seen by comparing the old and modern joints given in Table No. 9-A. Short bars of 20 to 24 ins. are almost invariably used in England. The length of bars is from 20 ins. with four bolts, on the Boston & Albany Ry., to 48 ins. with six bolts, on the Savannah, Florida & Western Ry. These 48-in. bars are being gradually replaced with the standard 26-in. four-bolt bars of the Plant System, while the old 48-in. bars of the Lake Shore & Michigan Southern Ry. were replaced by 32-in. bars with six bolts, and later by 24-in. bars with four bolts. The logic of the very long bars is hard to see, especially where the bolt holes are several inches from the ends, as the metal beyond these holes does little service. The old 36-in. bars of the Concord & Montreal Ry. had four bolts 6-ins. c. to c., leaving 9 ins. free beyond the end bolts. The best lengths appear to be 20 to 24 ins. for supported joints, 24 to 30 ins.

for suspended and bridge joints, and 30 to 36 ins., for three-tie joints. The bolt hole spacing formerly ranged as high as 12 ins., but 9 ins. is now about the maximum, and even that is exceptional, the more common practice being to space the bolts 4 to 7 ins. c. to c. Very wide spacing is objectionable, and it is advisable to get the center bolts as near as possible to the ends of the rails, while still leaving metal enough to ensure against cracking or fracture of the rails. Table No. 9-A shows the arrangement of a number of joints, and further particulars will be found in the tables of track standards at the end of the book.

TABLE NO. 9-A.—RAIL JOINTS.

Railway.	No. of bolts.	Length of bar, ins.	Spacing, c. to c. of bolts. Middle, ins.	Intermediate, ins.	End, ins.	Type of joint.	Weight of rail.
Sav., Fla. & West. (old)	6	48	6	12	6	3-tie.	75
Lake Shore & Mich. So. (old).	6	48	6	6	11	Supported.	70
Canadian Pacific (old)	6	44	5¼	6½	9¾	3-tie.	72
Erie (old)	6	40	8	6	7	Suspended.	80
Chic., Burl. & Quincy	6	38	5	5	5	Suspended.	75
New York Central	6	36	5.6	5.6	5.6	3-tie.	80 to 100
Pennsylvania	6	34 & 30	4	5	6	Suspended.	85 to 100
Norfolk & Western	6	30	5 5/16	5	5	"	85
Erie	6	30	4 3/16	4¾	4¾	"	90
Union Pacific (new)	6	29	5	4½	4½	"	80 to 90
Lehigh Valley	6	28	4	4	4	"	90 to 100
Concord & Montreal (old)	4	36	6	..	6	"	72
Canadian Pacific (new)	4	26	5 3/16	..	6½	"	80
Chicago Great Western	4	26	6	..	6	"	75
Chicago & Northwestern	4	26	6	..	6	Bridge.	90
Southern	4	26	4	..	7	Suspended.	80
Lake Shore & Mich. So. (new).	4	24	6	..	5	Supported.	80
N. Y., N. H. & H.	4	24	5	..	7	Suspended.	100
Louisville & Nashville	4	22⅛	5⅛	..	6	"	80
Boston & Albany	4	20	4¾	..	4¾	Supported.	95

Bolts and Nuts.—Track bolts are now usually made of mild steel and are ¾ or ⅞-in. diameter, a very few roads having them as large as 1-in. for heavy rails, while ⅞-in. and 1-in. bolts are used for frogs. They are 3½ to 4¾ ins. long under the head, according to the style of joint, but should not project more than ¼-in. beyond the nut. They are put up in kegs of about 200 lbs. A keg contains about 250 bolts ¾ × 3½ ins., with nuts 1¼ ins. square; 208 bolts ¾ × 3¾ ins., with 1½-in. nuts; 220 bolts ¾ × 4 ins., with 1¼ in. nuts; or 195 bolts ¾ × 4¼ ins. with 1½ in. nuts. The bolts should be straight and smooth, with well cut threads, and the threaded portion should be as short as possible, so as to give the body of the bolt a full bearing in the splice bar. The threads should be of U. S. standard, so made on both bolt and nut that the nut can be screwed on by hand only for the first three or four threads, after which it must be turned by the wrench, the fit not being so tight as to burst the nut or distort the threads in screwing up with an ordinary track wrench. The Harvey grip-thread bolt, Fig. 45, is of mild steel and has the thread spun up on the body by a cold rolling process, the threads rising 1-16-in. above the body of the bolt, while in the ordinary bolt (like that of the Pennsylvania Ry., Fig. 45) the thread is cut out of the body and so reduce the thickness at the root. The Wrenshall oval bodied bolts have been extensively used, but on account of the higher cost their use has been practically discontinued. Those on the Northern Pacific Ry. were ⅞ × 11-16-in. in the body, and 1 × ¾-in. in the neck, with a head of 1 7-16 ins. diameter.

The track bolt has usually an oval or square neck under the head, fitting into a hole of corresponding shape in the splice bar, in order to prevent the bolt from turning while the nut is being screwed on or off. The length of the neck should be equal to the thickness of the splice bar. The bolts usually have cup heads, but the heads are often too small and too thin at the edge, so that the wear in the edge is likely to soon reduce the bearing surface, especially as the contact surfaces are often too rough for a good bearing. It might be better to use a square or T head, and if a grooved splice bar was used with these (as on the Boston & Albany Ry., Fig. 39), or if an L-head was used, bearing on the flange of the angle bar, there would then be no necessity for a neck on the bolt, and both bars could be drilled or punched alike. In some joints, the bolts are tapped into the bar, nuts being omitted or else used as locknuts. This necessitates extra expense in manufacture, and any injury to one threaded hole renders the whole bar useless. If nuts are also used, the expense is still greater.

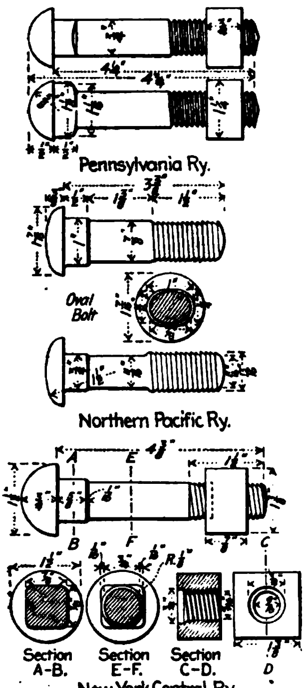


Fig. 45.—Track Bolts.

The nuts should be well formed, with true and clean cut threads, and should be thick enough to give a good bearing, as thin nuts result in loose nuts and damaged threads. Both square and hexagonal nuts are used, but the former are by far the most general. The corners are sometimes chamfered toward the inner face, in order to give a better hold for the wrench. The nuts may be on the inside or outside of the rail, but the former is the most approved practice, though with light rails it is sometimes necessary to put them on the outside, to be clear of the wheel flanges. The New York, New Haven & Hartford Ry. puts them alternately on the inside and outside of its 100-lb. rails, so as not to have all the bolt necks on one side, and to prevent derailed wheels from breaking all the bolts of the joints. A nut-lock is usually placed between the nut and the bar, to prevent the nut from slacking. Lock nuts, however, render these unnecessary, and thus reduce the number of parts. The Harvey grip-thread bolt has a ratchet thread, undercut on the bearing side, or about 5° less than a right angle to the axis of the bolt. The nut has a similar thread, the bearing side of which is about 5° greater than a right angle to the axis of the nut. The thickness of face of thread and depth between threads is increased towards the outer end of the nut by flattening the angle of the thread. When the nut is screwed hard against the splice bar, the thin sharp threads of the bolt are upset so as to fill the space of 10° between the threads of the bolt and the nut. The hole in the nut is enlarged at the

bearing face, forming a chamber 3-16-in. deep; thus ensuring good threads to screw the nut upon in taking up any slack. The Oliver or "Holdfast" nut has the three outer threads of the ratchet form and cut at a slightly different angle from the others, thus setting up a tight grip on the bolt. The National elastic nut is made from a flat strip so shaped as to form a dovetail, scarf or halved joint when bent into a ring. The rough ring is then pressed into hexagon form and tapped slightly smaller than the bolt, so that when put in with a wrench it opens about 1-64-in. at its joint and exerts a grip on the bolt. The nut can be easily slackened or tightened, and causes no injury to the threads of the bolt. The Automatic nut is of T shape, the wings being slightly curved to act as a spring. The bolt is

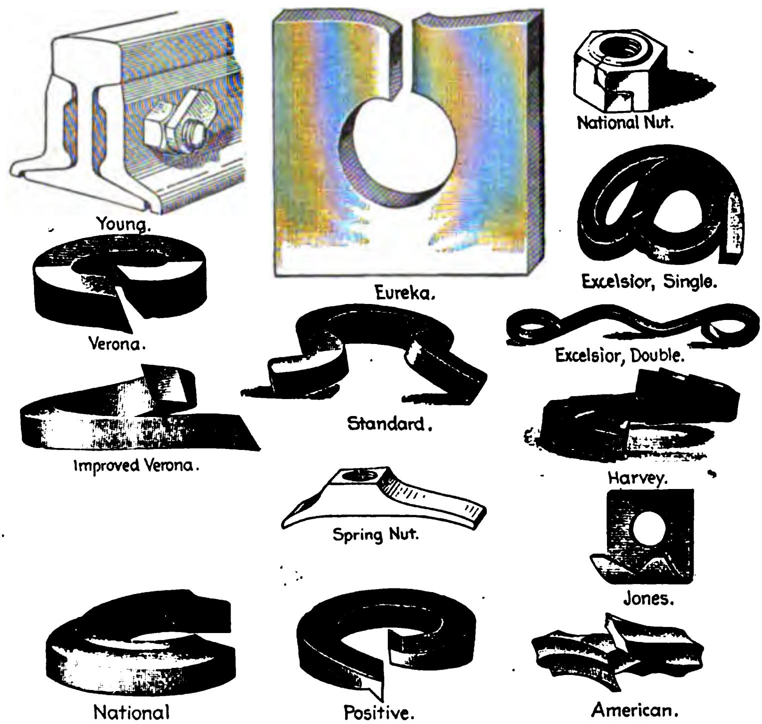


Fig. 46.—Nutlocks.

screwed into the nut, drawing it flat against the splice bar, the spring action of the wings then preventing it from slacking. This device has been successfully used at frogs, crossings and guard rails, where heavy strains came upon the bolts.

Nutlocks.—Of the numerous designs in use, the majority are in the form of spring washers. Probably the most extensively used is the Verona, which is a steel split washer twisted spirally to give about ¼-in. opening. Many modifications of this design have the metal twisted, jagged or pointed so as to cut into the softer metal of the splice bar, but the advantages of such

practice are dubious. Some nutlocks are made to fit a pair of bolts, like the Excelsior double nutlock. The spring action is not the only principle adopted. The Jones nutlock is a thin flexible plate, the edge of which comes against the rail head or splice bar, while one end is bent up against the nut when the latter is screwed home. The Stark nutlock has a keyway on the bolt and eight keyways in the nut, so that at each one-eighth turn of the nut a slot is formed to receive a split pin. The Young nutlock is an oval washer with the bolt hole near one end; this is screwed on after the ordinary nut and the weight of its longer end prevents it from working loose. Several forms of nutlocks are shown in Fig. 46.

Examples of Rail Joints.—The New York Central Ry. uses three-tie joints, Fig. 41, having ties 9 ins. wide, 6 ins. apart, with splice bars 36 ins. long. On the middle tie is a three-flanged Servis tie-plate, 9¾ × 6 ins., 13-16-in. deep. One splice bar has holes 13-16-in. square, with rounded corners; the other bar has holes 13-16-in. diameter, while the rails have holes 15-16-in. diameter. The Harvey bolt is ¾-in. diameter, 4⅜-ins. long under the head, with a neck ⅞-in. square having ⅛-in. rounded corners; the cup head of the bolt is ¾-in. thick and 1½ ins. in diameter. The nut is 1⅜-ins. square, ⅞-in. thick. The old splice bars shown in Fig. 41 had the flanges extended but little beyond the rail base, and 1-16-in. clear of the tie. The new form takes a bearing on the tie, as shown at (A) Fig. 39. The Boston & Albany Ry. has a supported joint with 20-in. splice bars weighing 45 lbs. per pair, and four ⅞-in. holes, 4¾ ins. c. to c. The rails have 1-in. holes. The bars have heavy ribs at top and bottom, and wide flanges, with a 13-16-in. spike hole in each, the width of the joint over the flanges being 8 ins. The holes are 1 in. on opposite sides of the center line of the joint. The inner bar has a longitudinal groove to hold the bolt heads. The bolts are ¾-in. diameter, with double Excelsior nut locks. The Chicago & Northwestern Ry. has a four-bolt bridge joint, Fig. 42, with shoulder ties 9½ ins. apart in the clear. The bridge plate is channel shaped, 26 ins. long, 8⅛ ins. wide, ⅜-in. thick for 5½ ins. (to fit a 5⅜-in. rail base), and ⅝-in. for a width of 1 5-16 ins. at the sides. The splice bars are 26 ins. long, with bolts 6 ins. c. to c. They are thin, and the flanges are clear of the bridge plate, projecting over it far enough for the spike slots to register with square holes in the plate. One bar has oval holes, 15-16 × 1 5-16 ins., while the other has holes 1 1-16-in. diameter. The Harvey bolts are 13-16-in. diameter, 3 13-16 ins. long under the head, with a neck 13-16 × 1⅛ ins., 9-16-in. long. The nut is 1 7-16 ins. square and 1 in. deep, with chamfered corners. The Louisville & Nashville Ry. has a suspended six-bolt joint, with shoulder ties 7 × 9 ins., 9 ft. long, 10 ins. apart in the clear. The splice bars are 29 ins. long, with bolts spaced 4⅛-ins. at the middle, 4½ ins. intermediate and 6 ins. at the ends, leaving only 1 15-16 ins. beyond the center of the end bolt holes. The spike slots are 6 and 4 ins. from the ends of the bar, ¾-in. wide and 9-16-in. deep. The outside bar has oval holes 1 × 1¼ ins., while the inside bar and the rails have holes 1 in. diameter. The Chicago, Burlington & Quincy Ry. has three-tie joints with shoulder ties 8 ins. wide and 8 ins. apart in the clear. The splice bars are 38 ins. long, with six 15-16-in. bolt holes, 5 ins. c. to c. The bars are clear of the ties (C, Fig. 39) and weigh 63.75 lbs. per pair. The six bolts, nuts and nutlocks weigh 8.26 lbs.; making the total weight of splice about 72 lbs. The spike slots are ¾-in. wide and ⅝-in. deep,

and are 3⅞ ins. from one end and 1⅞ in. from the other end of the bar. The bolts are ⅞-in. diameter, 4 ins. long under the head, the head being 1 7-16-ins. square and 13-16-in. thick. The nut is square, ⅞-in. thick, and the nutlock 1 3-16-ins. diameter and ¼-in. thick.

Track Material.

The quantity of track material for one mile of single track, with 30 ft. rails (giving 352 joints) is given in Table No. 10, together with a general estimate of cost at the prices of December, 1899. It may be noted that with rails 33 ft., 45 ft. and 60 ft. long, the number of rails per mile will be reduced to 320, 234.6 and 176 respectively. The weight of rails per yard divided by 7 and multiplied by 11 gives the weight in gross tons (2,240 lbs.) per mile of single track (two rails).

TABLE NO. 10.—QUANTITIES AND PRICES OF TRACK MATERIAL.

	No.		No.
Rails, 30 ft. long	352	Track bolts (6-bolt joints)	2,112
Ties, 16 per rail	2,816	Nuts (4-bolt joints)	1,408
Tie-plates (2 on each tie)	5,632	Nuts (6-bolt ")	2,112
Splice bars	704	Nut locks (single) (4-bolt joints)	1,408
Joint bridge-plates	352	" " (6-bolt ")	2,112
Track bolts (4-bolt joints)	1,408	Spikes or screws, 4 per tie	11,264
Clips for screw spikes, 4 per tie	11,264		

	70-lb. rails.	90-lb. rails.
Rails, $35.00 per ton	$3,850	$4,950
Spikes, $^9/_{16}$-in. x 5½ ins., $3.00 per 100-lb. keg	198	198
Angle bars, $2.75 per 100 lbs.	387	435
Bolts and nuts, $4.00 per 100 lbs.; Washers, $10.00 per 1,000; Braces, $30.00 per 1,000	141	146
Ties, 75 cts.	2,250	2,250
Tracklaying, including construction train	690	690
Ballast	1,050	1,800
Total	$8,566	$10,469

CHAPTER 7.—SWITCHES AND FROGS.

The switch is the device by which a train is diverted from one track to another, and the split switch (now almost universally used) was introduced in England as early as 1825. In this country, however, the stub switch was generally employed, and it is only within recent years that the split switch has become the standard type. The stub switch is now rarely used except in sidetracks and yards. The switch angle is that contained between the two positions of the rail in a stub switch, or between the switch and stock rails of a split switch. A switch is right or left handed according as the turnout is to the right or left of a man standing on the main track and facing the turnout. The Duggan switch, with pivoted rails moving vertically, was introduced a few years ago, but it was found that the diversity of distance back to back of wheels led to derailment. It was therefore not suitable for the high speed service for which it had been claimed to be especially adapted, and its use did not extend.

Stub Switch.—This consists of two movable rails, having the heels (or ends furthest from the diverging tracks) spliced to the track rails, while the free ends slide so as to coincide with the stub or fixed rails of one or other track, as shown in Fig. 47. The rails are connected by tie-rods, so as to

act together, and the throw or movement of the free ends is usually 4 or 5 ins. They are usually 30 ft. long, and are spiked to the ties for a certain distance beyond the heel, this distance being about 5 ft. for a 7½° curve and 12 ft. for a 15° turnout curve. If only hinged by the splice joints at the heel, the rails will not be curved when set for the turnout, but will remain straight, thus forming an angle or kink at the heel and toe. When spiked for a certain distance (depending upon the frog number) the rails

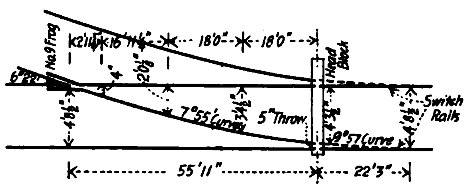


Fig. 47.—Stub Switch.

when set for the turnout will be sprung to approximate to the proper curve. The toe of each rail rests on a head plate or head chair, Fig. 48, about 10 x 16 ins., which has lugs to limit the throw and is also formed to hold the ends of the stub rails and keep them from creeping. These rails should also be bolted together, a filler block being placed between the webs, and sometimes a U strap is bolted around the ends of the webs. Cast iron is liable to fracture, and wrought iron or cast steel are preferable, the base plate being about 1 in. thick. The head chairs are spiked to a heavy timber head block about 8 x 12 ins., 12 to 16 ft. long, the end of which carries the switchstand. This form of switch is neither safe, efficient, nor economical, even when fitted with such devices as the safety castings of the Tyler and Cooke switches, which move with the rails and carry wheels coming along the wrong track, which would otherwise drop off the ends of the stub rails onto the ties. The space between the ends of the switch and stub rail is often as great as 2 ins., causing severe wear to wheels and switch. On the other

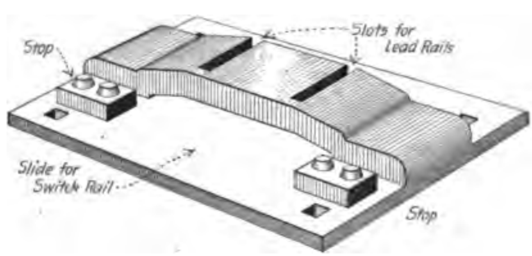


Fig. 48.—Head Chair for Stub Switch.

hand, the switch rails may expand in hot weather so as to be jammed in the head chair, though this may be avoided to some extent by beveling and lapping the rail ends for about 12 ins., as at drawbridge connections. Under heavy traffic it is difficult to keep stub switches in proper condition. In yards having such switches, a large proportion of the track work is in maintaining and repairing the switches, and replacing switch rods and connections damaged by derailments.

Split Switch.—This consists of two point or switch rails (straight or curved to fit the curve of the turnout), planed tapering to a vertical edge, so that the ends will fit close against the main or stock rails. The heels of the switch rails are towards the diverging tracks, which is the reverse position from that of the stub switch rails. The two outer rails of these tracks are continuous, the outer rail of the main track continuing unbroken, while the inner rail follows the curve of the turnout. The switch rails are between these stock rails, with a space of about 5 to 6½ ins. between the gage lines at the heel, or a clearance of 2½ to 3½ ins. (preferably 3 ins.) between the rail heads. The throw of the point ends is 3½ to 5½ ins., so that when one switch rail is home against its stock rail the other is 3½ to 5½ ins. from the other stock rail. About 12 or 16 ins. ahead of the point, the stock rail on the turnout side is given a decided kink or bend by means of a rail bender, so that when set for the main line, the gage sides of the stock and switch rails will be in exact alinement. The switch rails are connected by switch rods or tie rods, generally three to six in number, though some roads use only one, placed close to the point. The rods are either round or flat, with jaws on the ends to receive the angle clamps bolted to the webs of the rails, and the end switch rod or head rod should be adjustable, so that wear or slack can be taken up to keep the gage true. Very often this is done by placing washers on the bolts which fasten the head rod to the rail, but this is bad practice. In modern switches the adjustment is made by turnbuckles or fixed clevises, each end of the rod having a right hand thread. The gage is not affected by turning the rod or turnbuckles (as by persons tampering with the switch), but the rod must first be disconnected and the bolts removed from the end fastenings. Some roads, however, prefer to use rigid or non-adjustable rods. The rods should lie between ties spaced about 4 ins. apart, to protect them from injury in case of derailment. To the head rod is attached the connecting rod from the switchstand. The stock and switch rails rest on flat steel plates on each tie, which prevent the rails from cutting the ties (with consequent tilting of rails and widening of gage), and form slide plates for the switch rails. Each plate may have a lug to hold the heel of a rail brace on the outside. On the tie at the point of the switch should be a plate extending along the tie under all four rails, so as to assist in maintaining the gage, having shoulders or lugs to fit the outside edges of the stock rails and lugs to fit the heels of the rail braces.

The standard split switch for 85-lb. rails on the Norfolk & Western Ry. is shown in Fig. 49. The switch rails are 15 ft. long, connected by two rigid tie bars, ¾ × 3 ins., set on edge, having riveted jaws bolted to the rails. Formerly, 18-ft. switch rails were used, with five rods. The throw of the switch is 3½ ins., and the width over gage lines at the heel is 6¼ ins. Rail braces are put at the heel and on six ties at the point. About 5 ft. from the heel is a stop lug, riveted to the switch rail, so that when the rail is home this will bear against the web of the stock rail, and prevent the pressure of the wheel flanges from bending the rail. There are 18 slide plates; Nos. 1 to 6 are 18 9-16 × 5 ins., ½-in. thick for 9 13-16 ins., and then 13-16-in. thick; the other three are 14 9-16 × 4 ins., with the raised part 7¾ ins. long, and thicknesses as follows; No. 7, ⅝-in. and 11-16-in.; No. 8, ⅝ and 19-32-in.; No. 9, ⅝ and ½-in. All have ¾-in. spike holes. The switch rails are

planed to fit closely against the stock rails for 5 ft. 7¼ ins. from the point, and the inner edge is planed off for 7 ft. from the point.

The length of switch rail is usually 15 or 18 ft., and since the first edition of this book the Norfolk & Western Ry. has changed its standard from the longer to the shorter length. Rails 19½, 20, 21, 22, 24, 28 and even 30 ft. are used, the latter being employed where double track changes to four track (on the Pennsylvania Ry.) and to single track (on the Cleveland, Cincinnati, Chicago & St. Louis Ry.), the switches being used at high speed. On the long switch rails in 125-ft. leads of high speed switches at the junction of four-track and double track sections, the Erie Ry. uses three stops or filler blocks to support these rails against the stock rails. If a 30-ft. rail is cut in two pieces, 15 ft. 1 in. and 14 ft. 11 ins. long, and these are

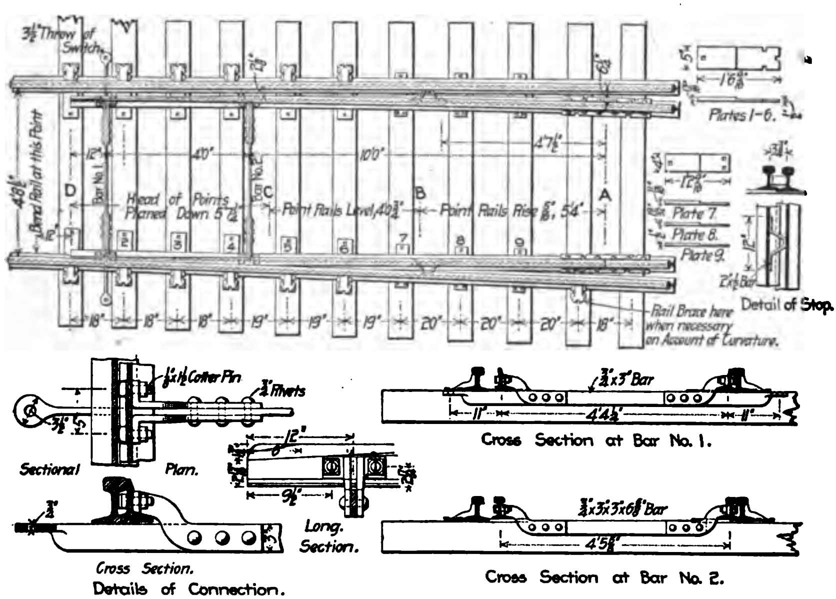


Fig. 49.—Standard Split Switch; Norfolk & Western Ry.

placed in the curved and straight track respectively, the heels will be exactly opposite, so that the joint ties at the heel will be square across the track. For switches leading from the outside of curves on main line, the switch rail on the inner side of the main track should have its point about 24 ins. in advance of that of the other, with a guard rail opposite to guide the wheels in the reversal of the centrifugal motion of the train and prevent undue wear on the switch rail. Switch rails 10 and 12 ft. long are used in yards and unimportant tracks, but 15 ft. is the minimum for main track work. The end of the switch rail is left about ⅛-in. thick, and the top is planed down on a slope for 6 to 15 ins., giving a drop of ¾ or ⅞-in., below the top of the stock rail, the corner of the switch rail being rounded off vertically. This is to prevent wheel flanges from striking the point. In the Norfolk & Western Ry. switch, the head of the switch rail rises 5-16-in. in 5 ft. 4 ins.

from the heel, and is then level for 4 ft., beyond which it is planed down to the point, 5 ft. 7¼-ins. In other designs, the heads of the switch and stock rails are level at 12 or 15 ins. from the point, but then the former rises to ¼ or 5-16 in. above the latter in a length of about 3 ft. 6 ins. Beyond this, the head is sloped so that the rails are again level at the heel. The object of this is to carry worn or hollow tires and prevent them from cutting the stock rail. In the form of switch rail usually employed, the head and base are planed away on the inner side to allow the point to fit against the head of the stock rail (or in some cases even under the head of that rail at the extreme point), the base of the switch rail sliding up on that of the stock rail. As the switch rail is not parallel with the main rail, it is necessary, in order to obtain the feather edge at the point, to plane off a portion of the head and web on the outer side, so that the thin end of the switch rail is considerably weakened and its stiffness is reduced. This part of the rail may be reinforced by a flat or a T-iron riveted along the outer side of the web. In exceptional cases, the switch rails are locked in position by automatic devices, which ensure that the rails are properly set and prevent any movement.

Guard rails are sometimes placed close in front of facing switches in order to steady all car wheels and put them in proper line for taking the switch, thus preventing the points from being struck, and preventing sharp flanges from taking the wrong side of a loose switch rail not set well home. These guard rails are either parallel with the track rail, or so placed as to give the minimum width of flangeway just in front of the points. The Pennsylvania Lines use two straight 6-ft. guard rails, while the Boston & Albany Ry. has a single 10-ft. guard rail on the side opposite the turnout, this rail having its end 6 ins. from the switch point and giving a flangeway of 3 ins. at the heel and 1¾ ins. at the toe, the throw of the switch being 4½ ins. The Southern Pacific Ry. uses two 6-ft. guard rails with a 2-in. flangeway. These rails (Figs. 66 and 68) are not generally required for well-built switches having a throw of over 4 ins., except on sharp curves. It is, however, a good plan to put a tie-rod or bridle rod just in front of the switch, to prevent any widening of the gage; and also to use a long slide plate on the first tie, extending across the track, as already noted. In switches on the sharp right-angled curves of the Chicago elevated loop a guard rail is placed close to the stock rail on the side of the curve, and is extended back of the point of the switch rail. When the switch is set for the curve, the switch rail lies against the guard rail and is thus firmly supported to resist the blows from the wheel flanges in taking the curve. The Channel switch, Fig. 50, has a guard rail about 9 ft. long, bolted to the inside of each switch rail, with the proper flangeway provided by spacing blocks. The flaring ends of the guard rails extend beyond the switch rails, and have the head rod attached to them. No tie rods are used. Rail braces are generally placed outside the stock rail on at least two ties at the point, and sometimes back as far as the switch rail bears against the stock rail.

If very heavy switch rails were bolted up tight at the heel splices, they would not move freely. In the 100-lb. switches of the Southern terminal at Boston, two of the bolt holes in each rail are reamed out to 1⅜ ins., and a heavy gas-pipe thimble is put over the bolt through the rail. The thimble is long enough to take the pressure on the angle bar and prevent pinching

the rail. This allows the switch to move freely and yet leaves no loose nuts. On the Netherlands State Rys. each switch rail has a vertical pivot fitting in a casting bolted to the tie at the heel (no splice being used), and the switch and stock rails rest on a steel plate 19 ft. long and 13 ins. wide. The spread of the rails at the heel is often a little too wide, but the Bryant device used in all split and slip switches and movable point frogs at the above-

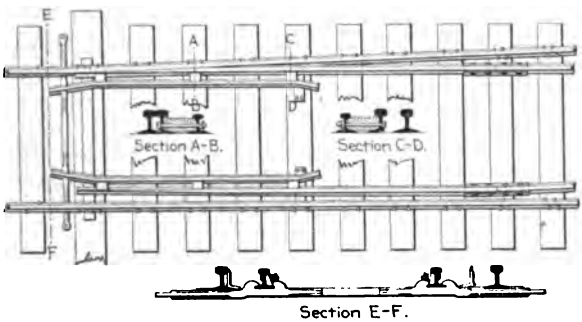


Fig. 50.—Channel Switch.

mentioned terminal (with 100-lb. rails) insures the proper spread and also prevents creeping of the switch rails. It consists of a splice trough or channel, 10 ins. long and 3 ins. wide, made of varying width to fit the angle between the rails. This is bolted between the angle bars of adjacent rails, or between the web of the stock rail and the splice bar of the heel joint. Stop lugs are sometimes bolted to the web of the switch rails, about 7 ft. to 10½ ft. from the point, so as to bear against the web of the stock rail when the switch is thrown, as already noted.

Automatic Switches.—In the Lorenz "automatic" switch, Fig. 51, the connecting rod from the switchstand is fastened to a strap surrounding a stiff spiral spring carried by the head rod. The rod passes through the spring, and the adjustment of length to make the switch rails fit properly

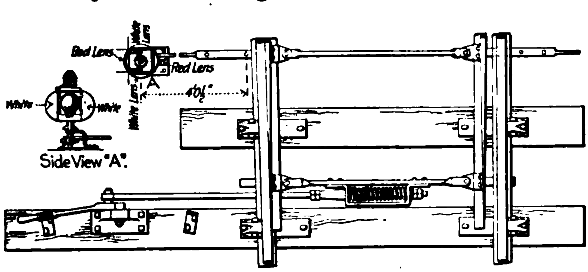


Fig. 51.—Lorenz Switch, with Ground Lever.

against the stock rails is effected by a nut at each end. The spring is stiff enough to make a rigid connection when the switch is operated from the switchstand in the usual way. If set for one track, and a train trails upon it from the other track, the pressure of the wheel flanges will force the switch rails over by compressing the spring, so that the train is not derailed and the switch connections are not broken. This type of switch

is now very little used, and the question of allowing trains to trail through closed switches is discussed further on, under the head of "Switchstands."

Slip Switches.—These are used at the intersections of diagonal tracks, where there is no room for an ordinary switch and turnout. The curves are necessarily very sharp, but the switches work very effectively in practice, and are largely used in yard work. A double slip switch is shown in Fig. 52. Such switches are not often used for main track connections,

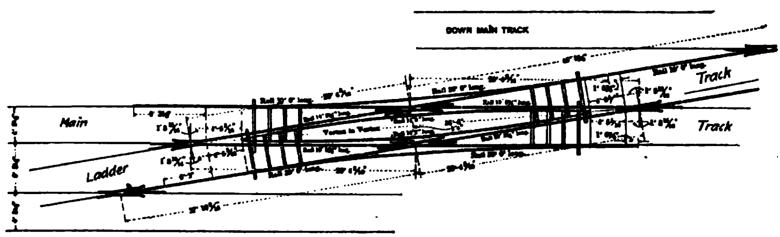


Fig. 52.—Slip Switches.

but at the Germantown Junction (Philadelphia) of the Philadelphia & Reading Ry., where the four-track line diverges to form two double-track lines, there are slips 112 ft. long, having No. 15 frogs and 28-ft. switch rails, so as to give easy and safe passage for high speed trains.

Three-Throw Switches.—In some cases, two turnouts diverge at the same point, requiring a crotch frog in the middle of the track, where the lead rails intersect. When permissible, it is better to set one switch a little in advance of the other, thus keeping the switch rails distinct, though this arrangement throws the crotch frog off the center line of the main track. Both plans are shown in Fig. 53.

Wharton Switch.—This type of switch gives an unbroken track when set for the main line, as in Fig. 54, while when set for the siding, it carries the wheels over the head of the stock rail by means of inclined rails. When set for the siding, the grooved switch rail (A), 8 or 9 ft. long, raises the outer wheels $1\frac{1}{2}$ ins. above the main rail, its heel bringing them upon the

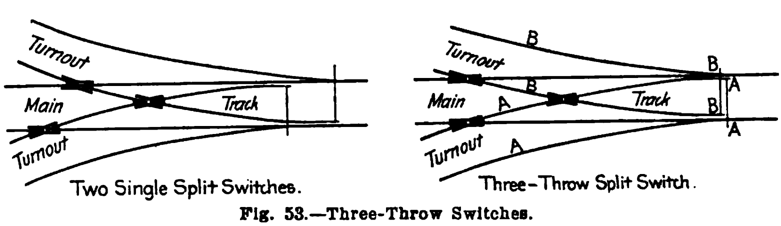


Fig. 53.—Three-Throw Switches.

raised lead rail of the turnout. At the same time, the elevating rail (B) on the outside of the main track, engages the outside of the treads of the inner wheels and raises them in the same way. If trailed through from the siding when set for the main track (as in Fig. 54) the wheels run upon grooved castings (C) and (D), the latter of which guides the inner wheels over the main rail, when the flanges drop into place. If trailed through on the main track when set for the siding, the wheels open the switch by forcing back

the pivoted guard rail (E), which rests against the main rail and is connected with the operating shaft (F) of the switch. The inside guard rail (G) should be not more than 2 ins. from the main rail, so as to force the wheels to mount the elevating rail (B) and keep them in position until the flanges have cleared the main rail. The elevating rail should also be set close to the main rail. A modified form is now made, in which all points are made from ordinary rails, the grooved rails being dispensed with. Owing to the sharp elevation of the switch rails this device is not adapted for high speed tracks, and has been largely replaced by the split switch. It is best adapted for lay-over sidings, etc., which are used only a few times daily and at speeds of not over 20 miles an hour.

MacPherson Switch.—In this, as in the Wharton switch, the main rails are left entirely unbroken when the switch is set for the main track. When set for the siding, the switch rails (which are slightly higher than the main rails) engage with the wheel treads, the inner switch rail lapping over the main rail. The wheels are thus raised sufficiently for their flanges to clear the main rails. This switch is the standard pattern on the Canadian Pacific

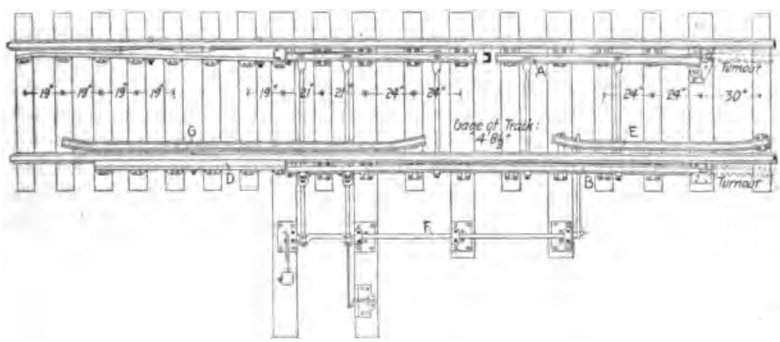


Fig. 54.—Wharton Switch.

Ry., and is used in connection with the MacPherson frog or frog substitute which is described further on.

Facing and Trailing Switches.—Any switch is a facing switch to trains running towards the point, and a trailing switch to those running towards the heel. In order to reduce the danger of derailment incident to facing switches, especially with high speed traffc, some double-track roads make their main line turnouts with trailing switches as far as possible. The Boston & Albany Ry. has about 90% of its switches so arranged on double track. In such cases, a train taking the sidetrack must trail through the switch, and then back through it as a facing switch. Where there is a down grade, however, on which a heavy train would have to be started and backed up grade through the switch, it would not be advisable to follow this practice.

Switch Protection and Derails.—Too many main line switches are inadequately protected, and the unprotected switch is one of the great dangers to traffic. Periodically, a careless or weary man leaves the switch open after his train has entered the siding, or thinks he has left it open and hastily

throws it when startled by the approach of a train, in either case causing a collison on the sidetrack. With almost equal frequency an engineman pulls out of a siding without orders, or thinking that the opposing train has passed, and so causes a collision. Accidents of the first kind may be prevented by the use of a distant switchstand, described later, or by a detector bar at some distance from the switch and connected to it, while a detector bar at the switch will prevent its being moved while a train is passing. The bar is somewhat longer than the greatest distance between wheels, and lies against the outside of the rail head, being hinged to vertical studs, so that in moving it must rise above the rail head, which the wheels prevent. The bars should always be fitted to switches in busy passenger yards. To prevent a car or train on the sidetrack from fouling or running onto the main track, a derailing switch with stub or split rail is placed on the outer rail of the sidetrack, being open (as a derail) when the switch is set for the main track. This may be operated independently, but is better when interlocked with the switch. The sidetrack may also be continued to a stub track beyond the derailing switch, which is normally set for the stub. This is somewhat more expensive, but prevents derailment, while ensuring equal safety, and the stub track may have its rails covered with sand to check the speed of cars. A derailing block or simple stop block is sometimes used in similar cases, generally on side tracks where cars are left standing. These prevent the cars from being accidentally or maliciously moved so as to foul the main tracks. All main line switches should be provided with distant signals, and those at passing places, yard entrances, etc., should be equipped with interlocking plants so as to prevent either of the kinds of accidents noted above. There are several designs of switches to be operated by the engineman, but they are based on the entirely wrong idea of letting the engineman interfere in regulating the train service, and such devices would almost inevitably result in disaster. There is, however, no fear of any such system being put in service.

Frogs.

The early frogs were of cast iron, but this is a poor material for the purpose and has long been abandoned. Cast steel has been used to a very limited extent in this country, and quite extensively abroad, the foreign frogs being reversible, so that when the top is worn the frog can be turned upside down and continued in service. With any but very stiff rails, however, the cast steel frogs are found to be rather hard riding, being rigid spots in a more or less elastic track. Frogs are now almost universally made of steel rails planed to shape, as shown in the diagram Fig. 55, the dotted lines indicating the rail connections. The shorter rail of the tongue should not be planed to a point, but its end should be about ¾-in. wide and dovetailed into the side of the longer rail. Usually the short point rail is placed on the turnout side, but in some makes it is placed on the main track, it being claimed that this is the stronger arrangement, and the one which will best withstand the destructive effect of hollow tires. Frogs with cast steel and manganese steel points and reinforcements to the wing rails at the throat are in use on tracks carrying heavy traffic.

The back of the frog, behind the tongue, is called the heel. The space between the tongue and the wing rail on each side is the flangeway or

flange space, in which is the flange filling composed of blocks fitted between the webs of the rails. Beyond the point, the space between the wing rails contracts to form the throat, with a width equal to that of the flangeway. and then widens out again to the toe (or mouth) of the frog. As a sharp point would soon be broken off, the point of the frog is made ⅜ to ½-in. wide, being a few inches short of the true or theoretical point. It is sometimes strengthened by a piece fitted between the head and base of the rail and welded against the web before the rail is planed. The base of the tongue rail should be left the full width at the point, the base of each wing rail being cut away to allow of the rails being brought close together. A raising block should be inserted in the angle of the heel, to raise the inner flange of a hollow tire and prevent it from exerting a bursting effect by wedging in this angle. Such tires are most destructive to frogs, as noted later. This block may also serve as an anchor block, being spiked to the tie to prevent creeping. At the heel of the frog are spliced the rails running from the tongue rails to the side track, while at the toe of the frog the lead rails running to the switch are spliced to the wing rails. In the diagram, Fig. 55, the head of the right hand wheel (running to the left on the main tracks) will engage with the upper wing rail and the main track lead rail. The left hand wheel (running to the right on the turnout) will

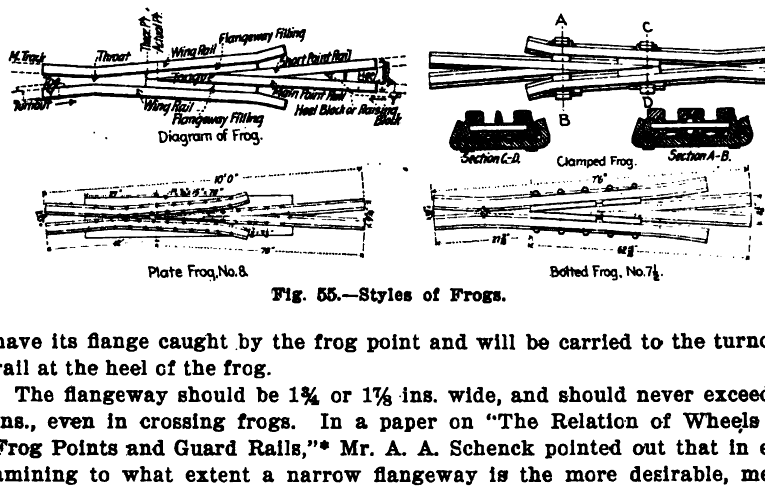


Fig. 55.—Styles of Frogs.

have its flange caught by the frog point and will be carried to the turnout rail at the heel of the frog.

The flangeway should be 1¾ or 1⅞ ins. wide, and should never exceed 2 ins., even in crossing frogs. In a paper on "The Relation of Wheels to Frog Points and Guard Rails,"* Mr. A. A. Schenck pointed out that in examining to what extent a narrow flangeway is the more desirable, mere width of tread bearing is not the only consideration, another important one being that simultaneous bearing on both frog point and wing rail is rarely secured, as one or other of these parts usually carries the entire weight. When both point and wheel are new, the bevel on the outer edge of the tread throws all the bearing on the frog point. A wing rail has the same effect when it is badly worn by false flanged wheels, is bent vertically, or yields under the load of the wheel. In such cases the width of flangeway is not of much importance. On the other hand, many frog points "duck" as the wheel approaches, leaving the wing rail to carry all the weight, and this is aided where the rail forming the frog point has a very

*Transactions of the American Society of Civil Engineers, May, 1894.

narrow base. In such cases, the width of tread bearing is important, to carry the wheel firmly until the depressed portion of the frog point has been passed. Hollow tires also prevent simultaneous bearing. It is therefore desirable to ignore the end of the frog point as a bearing, and to use a narrow flangeway and a small limit in wheel gage. This is referred to farther on in regard to the relations of wheels to frogs and guard rails. The destruction of a frog is due mainly to the shocks it receives, making it loose, and increasing the wear on such a loose frog so that it soon becomes unserviceable. Therefore the narrow flangeway will not effect a great increase in the life of the frog unless the frog is kept in good condition. The severest strain is generally assumed to be the blow upon the point, but it is probable that the lateral blow on the inside of the wing rail by the false-flange of a trailing wheel, and the wedging action of a similar wheel at the heel (unless a raising block is used) are even more destructive.

The number of a frog indicates the spread of the angle included by the tongue rails, the spread of these rails in a No. 8 frog being 1 in. in 8 ins. The number may be determined in various ways: (1) Measure the distance between points where the width over gage lines is 2 ins. and 3 ins.; this distance (in inches) will give the frog number; (2) Divide the length on gage line, from heel to true point, by the width over gage lines at the heel; (3) Take the sum of the width over rail heads at the heel and between rail heads at the toe, and divide this into the length on gage lines from toe to heel. The frog number is equal to the reciprocal of twice the sine of half the frog angle. The frog angle is that included by the tongue rails, and Table No. 11 gives the angle of the frog numbers generally used, together with the degree of turnout curve from a tangent. A right-hand frog is for a turnout to the right, as seen by a man standing in front of the switch. A crotch frog is placed at the intersection of the head rails of a double turnout (with a three-throw switch), and its number is equal to that of the main frog multiplied by 0.707.

TABLE NO. 11.—FROG NUMBERS AND ANGLES.

Frog No.	Frog angle degs.	Frog angle mins.	Turnout curve degs.	Turnout curve mins.	Frog. No.	Frog angle degs.	Frog angle mins.	Turnout curve degs.	Turnout curve mins.
No. 5.	11	25	24	03	No. 11.	5	12	4	58
No. 6.	9	32	16	40	No. 12.	4	46	4	10
No. 7.	8	10	12	17	No. 14.	4	05	3	04
No. 8.	7	09	9	23	No. 15.	4	24	2	40
No. 9.	6	22	7	25	No. 18.	3	11	1	52
No. 10.	5	44	6	01	No. 20.	2	52	1	28

It is desirable to have as few sizes of frogs as possible in regular service, and the general practice is to have but two or three standard numbers, using special frogs where necessary. Some roads even specify a single standard for main track and yards, but it is doubtful if they adhere very closely to the standard, especially in yard work. When standards are adopted, they should be introduced as rapidly as possible to replace the unsystematic arrangement of odd sizes and numbers of frogs which has been so general. If three numbers are made standard, they should be such that the lesser numbers will fit as crotch frogs of double turnouts, but such turnouts should not be used unless for special reasons. Nos. 7 to 10 are those in most common use. No. 4 is sometimes used for very sharp turnouts to warehouses, etc., but can only be used by switch engines with short wheel

base; its lead or turnout curve is of 150 ft. radius. A No. 5 frog is about the sharpest used in ordinary practice, and is for sharp turnouts in yards. No. 6 (or better No. 7) is used for ladder track connections, so as to occupy as little length of track as possible. Nos. 7, 8 and 9 are generally used in yards, Nos. 9 and 10 are used in ordinary main track, and should be the minimum for main line turnouts, crossovers, etc., which are frequently used by road engines. Nos. 12 to 18 are used for high speed turnouts, No. 15 having a lead curve of 3°. The Chesapeake & Ohio Ry. and Cleveland, Cincinnati, Chicago & St. Louis Ry. use No. 14 and No. 18, respectively, at the ends of double-track sections, and the Pennsylvania Ry. employs No. 24 frogs in special cases. The frogs should be carefully laid and bedded level on the ties, with plenty of good ballast underneath, as they are subjected to very severe blows. They should not be spiked to a gage ⅛-in. or ¼-in. slack, or wide, as is sometimes done, unless they are on curves where the gage is correspondingly widened. In other words, the gage at the frog should be exactly the same as that of the track in which it is laid. The laying of frogs is discussed in the chapter on "Switch Work and Turnouts."

Frogs are built up in various ways, as shown in Fig. 55. Bolted frogs have the parts held together by horizontal through bolts, ⅞-in. or 1 in. diameter, iron or steel fillers being placed between the webs of the point and wing rails. They are light, but the bolts are liable to work loose unless riveted over, keyed or otherwise secured, and the supposed advantage of being able to replace wornout parts without removing the frog is rarely availed of in practice. Yoked, clamped or keyed frogs have yokes which pass under the rail and have their ends opposite the webs of the wing rails. Fillers are placed between the tongue and wing rails, and steel keys are driven between the yokes and rails. One of the yokes or clamps should be placed at the frog point. The yokes or clamps are usually flat or T-shaped forged bars, but in the Strom frog they are 1⅛ ins. wide and 3 ins. deep, set on edge, with the ends formed to fit the head web and base of rail. These clamps are very stiff, and are held in place by two rods hooked over the ends of the wing rails and passing through both clamps, being secured by spring keys or cotters. Plate or riveted frogs have the rail bases riveted to a heavy rectangular plate, or to three or four plates which will fit between the ties. If one large plate is used, the lower rivet heads must be countersunk. The rivets are liable to work loose, so that the frog will be noisy and clattering. This old style of plate frog, however, is disappearing, but on many roads a combination style is now approved, having the rails bolted or clamped together (with the usual flangeway fillers between them), and riveted to a base plate. This makes a very substantial construction to withstand the effects of heavy traffic. In all filled frogs the fillers should extend about 8 ins. beyond the point, and back to the flare of the wing rails.

Long frogs make a much better riding track than short frogs. A good length is 15 ft., but lengths of 10, 12 and 14 ft. are also used. Yard frogs may be 6, 8 and 10 ft. long. It is well to have one of the tongue rails longer than the other, so that the splice joints at the heel will not interfere with each other. The wing rail for the curved lead rail may also be a little longer than the other, as the curved lead (B-C, Fig. 57) is longer than the straight lead (A-C). If the straight lead of a No. 10 frog is 60 ft. (two lead

rails, 30 ft. and 22 ft.; toe of frog to frog point, 8 ft.), then the curved lead will be nearly 2 ins. longer. This will bring the switch connecting rods 2 ins. out of square, which can be avoided by making the curved lead wing rail 2 ins. longer. If the wing rails are curved to fit the curve of the lead, they will make an easier riding track, but this is a refinement rarely practiced. (See also Chapter 22.)

The rigid frogs for 85-lb. rails on the Norfolk & Western Ry. are 15 ft. long, with a length of 8 ft. from point to heel and 7 ft. from point to toe. These dimensions are for Nos. 6 and 7 (special), and 8, 9, 10 and 12 (standard), but in No. 15 the lengths are 9 ft. 6 ins. and 5 ft. 6 ins., respectively. The plates are ¾-in. thick; 22 × 42 ins. for Nos. 6, 7, 8; 20 × 42 ins. for No. 9; and 20 × 60 ins. for Nos. 10, 12 and 15. They have ¾-in. rivets, with the lower heads countersunk, and ¾-in. spike holes. The frog point is ½-in. wide and the flangeways are 2 ins. wide. The ties are spaced 18 ins. c. to c. The Pennsylvania Lines West of Pittsburg issue complete specifications for switches and frogs, the dimensions and certain details being standard. The frogs ordinarily used are as follows: No. 15 spring-rail frogs for high-speed turnouts and crossovers; No. 10 and No. 8 spring-rail frogs for all other main track work; No. 7 rigid frogs for general yard work. Where turnouts or crossovers require frogs below No. 7, preference is given to Nos. 4 and 6. The rigid frogs are of the bolted and clamped types, made by various makers. A 2-in. flangeway is specified, measured ⅝-in. below top of rail, and the fillers extend 4 ins. ahead of the point. The lengths are as follows, measured along the rails:

No. of frog.	Length from point, To toe, ft.	Length from point, To heel, ft.	Total length, ft.	No. of frog.	Length from point, To toe, ft.	Length from point, To heel, ft.	Total length, ft.
3 to 6, inclusive..	4	6	10	11 to 12, inclusive..	8	10	18
7 " 10, " ..	6½	8½	15	13 " 15, " ..	8	12	20

Table No. 12 gives the dimensions of some rigid bolted frogs:

TABLE NO. 12.—DIMENSIONS OF RIGID BOLTED FROGS.

Frog No.	Length: Heel to point, ft.	Length: Total, ft.	Length: Wing rail, ft.	Length: Wing rail, ins.	Length: Filler, ins.	Spread: Toe, ins.	Spread: Heel, ins.	No. of bolts
4	5	8	7	2	36½	8½	15½	7
5	5	8	7	2	36½	6 11/16	12½	7
6	5	8	7	2	36½	5½	10½	7
7	5	8	7	2	36½	4⅝	9 1/16	7
8	8	15	11	2	36½	10	12½	7
9	8	15	11	8	42	8 3/16	11 3/16	8
10	8	15	11	8	42	7⅝	10⅛	8
11	10	17	11	8	42	7⅛	11 7/16	8
12	10	17	11	8	42	6½	10½	8
13	10	17	12	2	47½	5 15/16	9¾	9
14	12	19	12	2	47½	5½	10 13/16	9
15	12	19	12	2	47½	5⅛	10⅛	9

Spring-Rail Frogs.—All the frogs so far described are of the rigid type, in which there is necessarily a jolt as each wheel crosses the flangeway, this jolt being very severe when wheels or frog are worn. In first-class main track the spring-rail frog is now almost universally used, and makes a smooth riding track, as it gives an unbroken main rail. It is therefore specially adapted for turnouts where the main line carries heavy and fast traffic, as it makes a safer and better riding track and diminishes the wear and maintenance work, the frog keeping in better surface than the rigid

frog. The principle of the spring-rail frog is explained by Fig. 57. The lead rails are (A) and (B). The turnout wing rail (C) is hinged and is normally held against the frog point by a spring, so that wheels (X) on the main track have no flangeway to cross, but have a continuous bearing. The main track wing rail (D) is fixed. The wheels on the turnout, (Y) and (Z), force the spring wing rail (C) back by the wheel flanges entering between

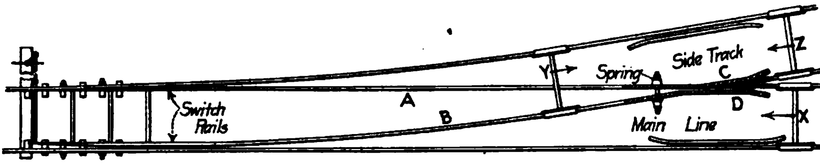


Fig. 57.—Diagram of Spring-Rail Frog.

the wing rail and frog point. The spring-rail frog is not generally required at junctions or in heavy yards, though it may be used for thoroughfare or open tracks in yards. At some junctions, however, where there is heavy traffic on both tracks, or where a double-track junction turnout runs into a single-track branch, a double spring-rail frog is used. This has both wing rails movable and both normally resting against the frog point.

The spring is often placed near the throat, but it is better to have it near the free enu of the rail, while in some cases an additional spring is placed at the throat. The outward movement is about 2 ins., limited by stops or rail braces. To prevent the end of the spring rail from tilting up when the wheels pass the throat, hinged holding-down arms may be used, pivoted to the base plate and to an eye in a strap riveted to the web of the rail. Bars on the rail sliding in sockets on the plate are also used for this purpose. The frog point and the end of the spring rail should rest upon a base plate at least 3 ft. long, and the rail should fit against the point for a sufficient length to give a full bearing to the wheels. The standard No. 10 spring rail frog of the Illinois Central Ry. is shown in Fig. 58. It is 14 ft. long,

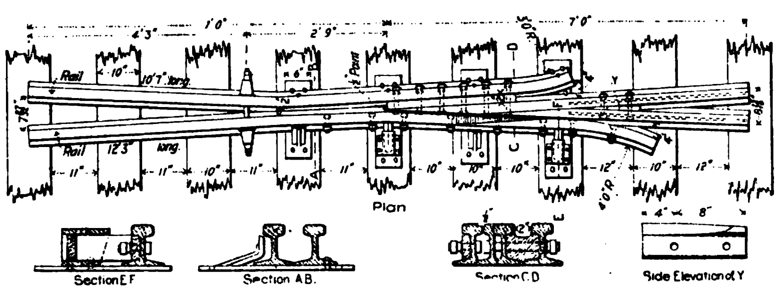


Fig. 58.—Spring-Rail Frog, No. 10; Illinois Central Ry.

with the frog point 7 ft. from toe and heel, and has the spring near the throat. The spring rail is 12 ft. 3 ins. long, with a limit of movement of 2 ins., which is the width of throat and flangeway. The top is planed down to allow the free passage of the false flange of a worn wheel, thus preventing such wheels from forcing the spring rail outward, while the rail is guided and kept in its horizontal position by means of two bars sliding in sockets

or cuffs riveted to the ½-in. base plate. In the open flangeway is placed a filler 30 ins. long, extending back from the frog point.

A short guard rail or reinforcing rail outside the spring rail is sometimes provided as a means of extra security in case of fracture of the spring rail. The Eureka frog (Fig. 59) has the spring rail proper extending only beyond

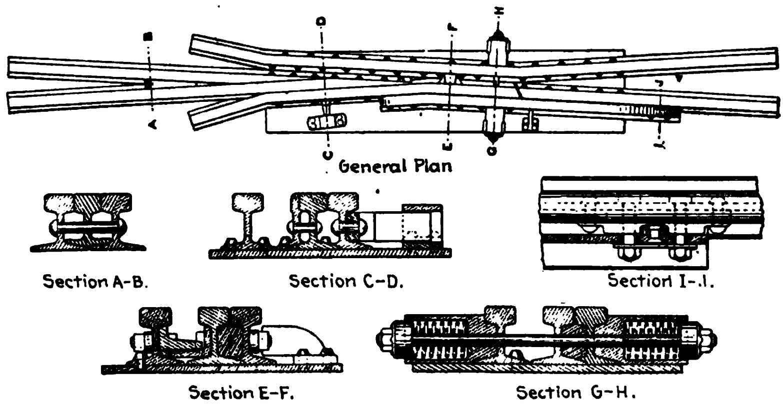


Fig. 59.—Eureka Spring-Rail Frog.

the throat of the frog, the part of the wing rail towards the switch being riveted to the base plate. An outer, or "hinge" rail, is bolted to the fixed and moving parts of this wing rail, these parts normally forming a continuous running rail with a miter joint at the throat of the frog. In the Vaughan frog, and in some others, the spring rail is pivoted at its outer end, or at the heel instead of the toe end of the frog. It does not extend the full length of the frog, but only to the throat, and is controlled by a spring placed nearly opposite the frog point. In the ordinary frog the greater part of the spring rail is used as a part of the main track, but in the Vaughan frog only the end of the rail is thus used. The filling block is so shaped as to guide the wheel flanges in case of any failure of the spring, a rib on the block fitting under the head of the spring rail. The Pennsylvania Ry. uses a

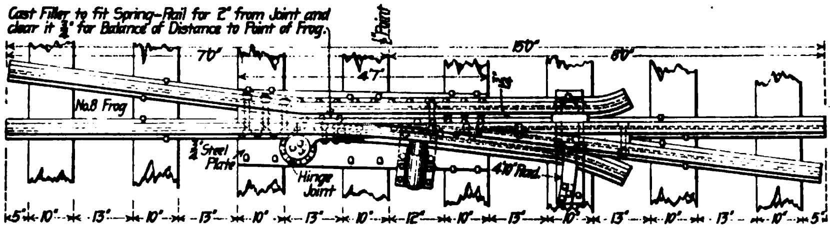


Fig. 60.—Swing-Rail Frog; Pennsylvania Ry.

spring rail frog very similar to that shown in Fig. 58, but having the spring about 18 ins. back of the point, while from a point 12 ins. back of the point the spring rail drops ⅜-in. to 2 ft. This railway also uses the hinged spring-rail frog (Fig. 60), which also has the spring opposite the frog point.

The point of the swing rail is located at the theoretical throat of the frog, and the rail is held down by a flat bar or strap passing through a slot in the web and attached to the point rail and slide plate. Devices have been introduced by which the spring rail is locked against the tongue when the switch is set for the main track, but these are very little used.

In the Jordan frog, used to some extent on the Michigan Central Ry., both wing rails lie normally against the frog point, and their ends are bolted to the tongue rails (with packing blocks between). The throat width is 1⅛ ins., and there is one double spring just beyond the throat. The pressure of the wheel flanges springs the rails outward so as to form a flangeway on one or other side of the frog point, the movement being limited by guides and stops riveted to the base plate. These are not satisfactory in yards, as the resistance of the rails checks the momentum of the cars in switching movements. Movable point frogs are mainly used as crossing frogs, as noted further on, but the Wood frog of this type (Fig. 61) has been extensively used in yards. There is no spring, but both wing rails move simultaneously, remaining in either position as set by the wheels. The Pennsylvania Ry. uses a somewhat similar yard frog, but having a spring on each side, 9½ ins. ahead of the point, with a filling block between the rails. Holding down arms are also fitted to the ends of the wing rails.

The impression prevails to some extent that the rigid frog, while perhaps less economical, is the safer in case of a broken wing rail, and that it offers

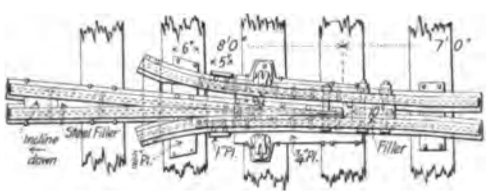


Fig. 61.—Wood's Moveable-Point Frog.

a better resistance to the destructive effects of hollow tires. Spring-rail frogs as now made, however, are as safe as, if not safer than, rigid frogs in case of breakage. With a worn frog or a hollow tire there is some possibility of the spring rail being forced out by a trailing main line wheel, the tread (with worn frog) on the false flange forcing it out to such an extent as to break the stops so that the wheel will drop into the throat of the frog. In some frogs this cannot occur, and it may be prevented by beveling or grooving the top of the spring rail, or making that rail ¼ to ⅜ in. lower than the top of the frog, so as to clear worn wheels. The former practice is the better. Accidents of this kind are very rare. The objections as to the clogging of the spring rail by snow and ice are found in practice to be of little moment. Spring-rail frogs are largely used on roads which have much snow and ice to deal with, and in fact they are now almost the universal standard for main track work.

Frog Substitutes.—In view of the increasing number and speed of trains and the number of turnouts, several devices have been introduced to avoid the use of the ordinary frog, and to give an actually unbroken main line rail. Some of these are in use, but not to any great extent. The principle

is the same in most cases. The turnout lead rail is inclined sufficiently to raise wheels so that their flanges will clear the main rail, the lead rail having a gap through which the main rail passes. In this gap works a pivoted rail or a crossing piece of special shape, operated in connection with the switch, and resting upon the main rail when the switch is set for the turnout. An automatic connection is provided, so that a main line train trailing through a switch set for the siding will throw the frog piece open and so set the switch in advance of the train. A careless man might sometimes throw a switch before a train taking the siding had cleared the frog, thus opening the frog and causing a derailment. A detector bar is therefore sometimes applied, as in interlocking work, to prevent the switch from being thrown until every wheel of the train has passed the fouling point. It has been objected that the connections between switch and frog are liable to derangement by creeping or expanding track, or by a car coming off the sidetrack when the switch is set for the main track. These objections, however, have little force when we consider the great extent to which interlocking apparatus and connections are in successful use. On some roads, also, all passing places are fitted with derails connected up to the switch, requiring longer connections than from switch to frog. The frog substitute has its limitations, the same as the spring-rail frog. It is not desirable for general use in yards, where quick switch throwing is necessary. For sidings in limited use, where the heavy wear of frogs (even spring-rail frogs) is disproportionate to the actual duty performed in carrying wheels in and out of the siding, it would be very desirable to have an unbroken main rail, and such situations open a field for the frog substitute.

One of the first of these devices to be put into actual service was that patented in 1884 by Mr. C. B. Price, now Division Superintendent of the Pennsylvania Ry. The movable piece to fill the gap in the lead rail is a large casting, but the wing rail also moves, so that it lies against the main rail when the switch is set for the siding. Just beyond the heel of the switch is a spring guard rail fitted against the gage side of the turnout rail so as to be operated by the wheel flanges. When this is pressed back by the flanges its hooked lugs engage with sockets on the operating rod, which is then locked so that the switch cannot be thrown until the last pair of wheels has cleared the frog. The MacPherson device is very similar, and within four years about 150 turnouts on the Canadian Pacific Ry. have been equipped with it, in connection with the MacPherson safety stub switch. It has shown but little wear, and the cost of maintenance has been small. Should a main line train trail through the device when set for the turnout, the wheel flanges would mount the incline of the heel of the crossing piece, the wheels running along this casting and down another incline upon the main rail again, the guard rail opposite the crossing piece holding the wheels over so that they cannot get on the wrong side of the main rail. When the head of such a train reaches the switch, each set of wheels would open it, but this would not throw the frog, owing to a spring connection in the switch rod similar to that of the Lorenz switch (Fig. 51). The frog cannot move until the switch lever is unlocked and thrown. The action of the device under these conditions has been proved in practice. The Coughlin spring-rail frog is also on the same principle, but the lead wing rail does not move. The only movable part is the frog piece or swing rail,

which is made from an ordinary track rail instead of being a heavy casting. The end of this rail has the web and base cut away to let the head swing across the main rail, while the ends of the lead rail are riveted to a base plate which also supports the main rail, these holding the parts in proper line and surface. These three devices are shown in Fig. 62.

Crossing Frogs.—Where two tracks intersect (as at grade crossings), crossing frogs must be used to give a flangeway in both directions, and as there is no uniformity in the angles, the crossings have generally to be

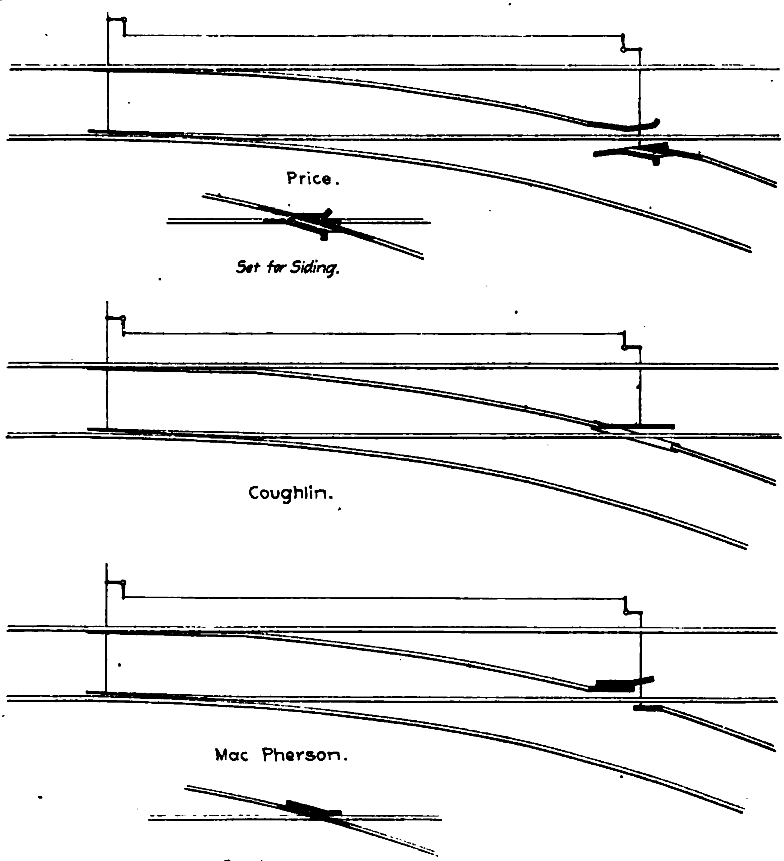
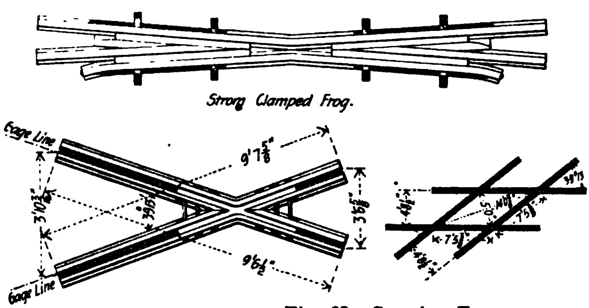


Fig. 62.—Frog Substitutes.

specially made for each case. They are usually of steel rails, fitted and bolted together, with filling pieces between, and should be riveted to base plates. The rail ends may be beveled off to a miter joint at the frog point, or have one rail butted against the other. The inner wing rail or guard rail is usually continuous in crossings of 45° to 90°, but is sometimes stopped and flared out at each corner. Both methods are shown in Fig. 63

and Fig. 97. At crossings on busy tracks, a third rail is sometimes placed against the outside of the track rail to carry the false flanges of badly worn wheels and prevent them from battering the rails at the flangeways. Crossings may be built up without a joint between the frogs, but this makes a very heavy section for transportation, and does not admit of repairs without taking up the crossing. As a rule it is better to have a joint in two sides. The sharper the angle of crossing, the greater will be the wear on the frogs, due to the battering effect of the wheels in jumping over the flangeways. With an angle of less than 8°, or where one or both tracks are on a curve, movable point frogs may be used, instead of crossing frogs. In this case there will be two pair of short switch rails set toe to toe, as shown in Fig. 64, and operated simultaneously by a lever. A similar arrangement may be applied at the crossing of slip switches. In the Norfolk & Western Ry. practice, as exemplified by a crossing of 98°, the entire crossing is in two pieces. Under each corner, or frog, is a ¾-in. plate, 24 x 36 ins., to which the rails are secured by ¾-in. rivets, 4 ins. pitch, having the lower heads countersunk. There are strips outside the rails and fillers between the main and guard rails, all held together by three bolts in each leg of the



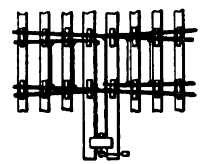


Fig. 64.—Moveable Point Crossing.

Fig. 63.—Crossing Frogs.

crossing. No satisfactory device to give a continuous rail for whichever track has been signaled has yet been brought forward. The Fontaine crossing, once used experimentally, had four movable corner pieces with a single groove or flangeway in each. These were riveted to horizontal rotating plates, which were operated simultaneously by rods connected to a wrist plate on a central vertical shaft interlocked with the signal apparatus.

For crossings of minor importance, as where street railways cross steam railways, the flange filling is sometimes inclined so as to carry the wheels of the street cars over the crossing on their flanges, thus giving an unbroken rail to the steam track. Where cable and electric railways intersect steam railways, regular built-up crossings are generally used, made with ordinary rails, and having a reinforcing rail placed outside of and touching the main rail. In some cases the rails of the electric track and the reinforcing rails of the steam track are planed down ⅝-in. or ¼-in. so as to clear all false-flanged wheels. This may be objectionable if four-wheel electric cars are run, but with double-truck cars very little shock is felt. The flangeway may be 1¾ ins. for the steam track, and 1¼ ins. for the electric track, the latter having a groove 11-16 in. deep through the rails of the former. In

order to reduce the wear of crossings of this kind in city streets, the rails of the steam track are sometimes of manganese steel, made in a special section combining the running rail, reinforcing rail and guard rail.

In the renewal of crossings, the angles should first be carefully measured, and the lines set out by instruments. It will very generally be found that the alinement has been affected by creeping of the rails, unless these have been anchored or secured by check plates. The gages of tracks should also be measured, so as to avoid badly fitting work due to a confusion of the gages of 4 ft. 8½ ins. and 4 ft. 9 ins. If the alinement is bad, the proper location should be made before the frogs are ordered, and a determination arrived at as to whether the frog is to be made to fit the alinement, or the entire crossing correctly realined. If the two tracks belong to different roads, this matter should be arranged before any work is done. If the two tracks have rails of different weights, the crossing should be built of the heavier rails, and a length or two of this rail laid beyond the frogs on the lighter track, so as to avoid excessive shock at the crossing. The light rails should have iron blocks or chairs and be spliced to the heavier rails by step joints. Further particulars in regard to crossings will be found in Chapters 9 and 22.

Repairs to Frogs.—When a frog has become worn, it makes a rough riding track and may be dangerous, so that prompt repair or renewal should be made. On roads where only slight repairs are made and all worn material goes to the scrap heap, there is much waste in throwing away worn frogs, as they are usually worn out in one part only. In order to effect a reduction in the expenses for new frogs and switch points, some roads have adopted a practice of having extensive repairs made by a good blacksmith. Thus when a frog is taken out it is sent to the shop to have a new wing rail put in, the point shimmed up to its proper level, or new bolts, rivets or keys put in, making the frog practically as good as new. New wing rails are made from pieces of good rail from the scrap pile, the old rails taking their place as scrap. Switch points may also be repaired in the same way.

Guard Rails.

Opposite the frog, and on the gage side of each of the running rails is placed a guard rail to hold the wheels in line and prevent them from striking the point or getting on the wrong side of the frog point. They are sometimes omitted in yards on account of the liability of the men to stumble over them or to get their feet caught. They should be 12 to 15 ft. long, straight for 6 or 8 ft. at the middle, and then flared out to the ends so as to bring the wheels steadily into the flangeway. The ends should be about 4 ins. clear of the track rail. On some roads the rails are bent to a uniform curve and placed with the narrowest part of the flangeway opposite the frog point. This is based on the idea that the wheels should only be held over while passing the frog point and then immediately released, as to hold them any longer than this would result in extra wear of the frog and guard rail. The straight rails, however, are much to be preferred, and have usually the edge of the base planed away to allow of the guard rail being placed close enough to the main rail. The rails are usually spiked to the ties, and supported by rail braces, using not less than two braces on tan-

gents and four on curves, as noted under the head of "Rail Fastenings." It is better to fasten them to the track rail, so that the proper width of flangeway is permanently maintained. This may be effected by means of bolts or clamps, or a combination of these, with spacing blocks or fillers between the webs of the rails. In one form, the outer side of the clamp holds the base of the track rail and the inner side is bent to fit the guard rail like an angle bar, a bolt passing through the bar, both rails and the spacing block. A 15-ft. guard rail should have 8 or 9 ft. of its length ahead of the frog point. Light rails may be used, being mounted on combination chairs and braces to give them the proper elevation, as is done in the Southern Pacific Ry.

The easy riding of trains at turnouts and the durability of frogs depend largely upon the proper placing of the guard rails. The gage of track should be the same at the frog as at adjacent points, and should be accurately maintained. The standard guard rail gage is 4 ft. 5 ins. over the heads of wing and guard rails. The flangeway on tangents should be uniformly 1¾ ins. or 1⅞ ins., or even 2 ins. when the objectionable gage of 4 ft. 9 ins. is still in use. On curves, the flangeway should be the standard width, plus the amount of widening of the gage. The standard guard-rail gage adopted by the Master Car Builders' Association in 1894 has lugs 1¾ ins. wide and 4 ft. 5 ins. apart in the clear, giving a distance of 4 ft. 6¾ ins. from point of frog to gage side of guard rail, irrespective of the gage of track. The importance of accuracy and uniformity of flangeway width is not suf-

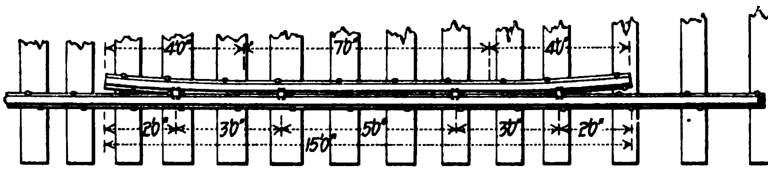


Fig. 65.—Standard Frog Guard Rail; Norfolk & Western Ry.

ficiently well understood by trackmen, and where the guard rail is independent of the main rail they will often merely guess at the width or vary it to suit their own ideas. The standard width should be insisted upon, and should be measured at the widest point of the rail heads (over the bottom of heads with flaring sides).

The Norfolk & Western Ry. uses a 15-ft. guard rail (Fig. 65), straight for 7 ft., with a flangeway of 1¾ ins., flaring out to 2½ ins. at 2 ft. from the end of the rail. This is for tangents and for curves up to 5°. On curves of 6, 7 and 8° (4 ft. 8¾ ins. gage), the flangeway is 2 ins. and 2¾ ins.; 9 to 12° (4 ft. 9 ins), 2¼ and 3 ins. The guard rails are spiked to the ties and bolted to the track rails with four bolts. The Pennsylvania Ry. uses a 15-ft. guard rail, straight for 3 ft. at the middle, and then curved for 6 ft. to a radius of 91 ft. to give a clearance of 4 ins. at the end. The rail has 8 ft. of its length ahead of the frog point. For frogs of 100-lb. rails, the Duluth & Iron Range Ry. uses guard rails of angle iron, ¾ x 6 x 6 ins., 20 ft. long, with 1¾ ins. flangeway for 8 ft., and then flaring out to a clearance of 4½ ins. at

the ends. The guard rails are secured to the track rail by seven ⅞-in. bolts with cast-iron spacing sleeves.

Footguards.

Accidents are continually happening to railway employees from their feet getting caught under the rail heads in the angles at the heels of frogs and switches, and at the flaring ends of guard rails. Being unable to free themselves, the men are often run over and either killed or maimed. These accidents are specially common in yards. It is now recognized that it is a humane and an economical precaution to fill in such places so that a man's foot cannot get caught in the space below the rail heads, and in some States the use of metal footguards is required by law. Wooden blocking is the most common form of footguard, but has the disadvantage of soon becoming broken and decayed, and is apt to be left neglected in such condition. The Hart footguard, however, consists of a strip of wood of triangular section bolted to the inner side of the web of each rail. The outer (sloping) face extends from the bottom of the side of the rail head to beyond the edge of the rail base. Gravel or cinder filling is also sometimes employed, but soon settles down or shakes out so as to lose its efficiency. Metal footguards are preferable, and several forms, patented and otherwise, are in use. One of these is an iron strap of the same height as the rail web, bent into a loop and driven between the rails. This plan, with a bar ⅝ × 2¾ ins., is used by the Norfolk & Western Ry. for rigid and spring rail frogs, heels of switches, etc. The National metal guard resembles a box open at the bottom and one end, being made of two pieces of sheet steel held together by two bolts and forced apart by springs. When being put in place, the sides are pressed together to allow the guard to be slipped in between the webs of the rails, and a spike or brace is put at the heel to hold it in place. Owing to its flexibility it can be used at the heels of switches and in spring-rail frogs. In the Green metal guard there are two horizontal plates, one under the other, held apart by springs and connected at the heel, the upper plate being formed to fit the rail head. In frogs, a special heel block or raising block sometimes acts also as a footguard.

Relations of Wheels to Frogs and Switches.

In 1885 the Master Car Builders' Association adopted as standard a distance of 4 ft. 5⅜ ins. back to back of wheel flanges, with a variation of 4 ft. 5½ ins. maximum and 4 ft. 5¼ ins. minimum. This standard is almost universally adopted, but in practice many wheels of improper gage are kept in service. These are very destructive to frogs, switches and guard rails, and are the probable cause of many "unexplained" derailments at such parts. A variation of ½-in. in wheel gage is sufficient, but it has been objected that to rectify all improperly gaged cars would cause serious expense and interruption to traffic. It is probable, however, that the number of such cases is insignificant as compared with the damage which they cause, and that the saving in maintenance of frogs, etc., would soon compensate for the expense. Similar trouble is caused by the use of cheap wheels having thick and irregular flanges, which do not conform to the standard form adopted by the Master Car Builders' Association. The trouble is aggra-

vated by the track gage of 4 ft. 9 ins. still used by some roads, and by the variations in shape of rail heads (having sharp or round corners and vertical or inclined sides), though this latter condition is becoming of less importance with the wide adoption of the uniform type of section recommended by the American Society of Civil Engineers.

It is an expensive practice to keep in service engines having worn or hollow driving-wheel tires, as the false flanges of such wheels are seriously destructive to frogs and switches, lead to much expense in track maintenance and repairs, and are liable to cause derailment. Worn blind tires, owing to their width, exert a powerful bursting force on frogs, switches and guard rails, which parts are not designed to stand such strains. Badly-worn tires on new rails with wider or flatter heads than the old rails, will slip and cause the engine to roll, to the detriment of the track and the reduction of the efficiency of the engine. Switch engines are often allowed to run with tires very badly worn, causing excessive wear of the track, and making it almost impossible to maintain the yard tracks in proper condition. If complaint is made, the motive power department is apt to claim that the engines cannot be spared to go into the shops, and the excuse is very generally allowed. It is, of course, a somewhat expensive and lengthy piece of work to run an engine into the shops, take down the rods, get the wheels out and turned, and re-erect all the parts. Some roads, however, keep spare wheels on hand, so that an engine can be sent out at once with a new set of wheels and the old ones turned at a convenient time ready for some other engine. This work, however, is required only occasionally, while the destruction of frogs and the excessive wear of track causes a continual drain on the maintenance expenses. "Tire dressing" brakeshoes, which bear on the whole width of the tread and also on the flange, are a great factor in increasing the mileage of the wheels before turning is necessary.

The permissible limit for depth of wear of tires in regular service should be ⅛ to ¼-in. for road engines, and ¼ to ⅜-in. for switch engines. It is not of much use to distinguish between passenger and freight engines, as they are frequently used in similar service, but the ⅛-in. limit might well be set for high-speed engines. The deep flanges are liable to break the track bolts, and the limit of depth of flange should be 1½ ins. for road engines and 1⅝ ins. for switch engines. The present limit of wear allowed by different railways ranges from 3-16-in. to ⅝-in., though wheels worn ⅝-in. hollow are sometimes met with in practice. Some roads insist upon the observance of the rule against a greater wear than ¼-in. on any engine, and this practice is to be recommended, but on many roads there is no general or observed rule. The roadmaster should have a tire gage, somewhat similar to the M. C. B. flange thickness gage, and promptly report any engines whose tires are worn beyond a proper limit. By putting a straight edge across the tread, the depth of groove can be measured with a rule. On the Chicago, Burlington & Quincy Ry. a gage is used, consisting of a steel plate with one edge formed to the standard outline of a new tire. This plate has a slide moving across it, with graduations on the slide and plate, as on a curve elevation gage. The gage is set on edge against the tire, fitting the flange and tread, and the slide pushed out until it touches the bottom of the worn groove, the scale showing the depth. On the Chicago, Milwaukee & St. Paul Ry., the Keen gage is used, having a number of small square pins in a

row between two plates. The frame is set across the tire, the pins being allowed to drop freely and then clamped, so that when the gage is removed the pins show the contour of the worn tire. The measurements are reported by the roundhouse foremen monthly, and the results are tabulated by the Motive Power Department in columns varying by 1-32-in. The allowable limit is ¼-in., but since the use of this gage tires are seldom worn more than 3-16-in. before being turned.

According to a committee report of the Roadmasters' Association of America in 1895, the damage to spring-rail frogs consists mainly in battering and shearing off the wing rails and point. It is on this class of frog that the greatest danger of derailment from hollow tires consists, for in trailing through the frog the tendency of the tire is to crowd the spring rail out. The tire also delivers a severe blow to both the point and wing rail, the latter becoming bent or strained in time. This retards the free action of the spring rail so that it cannot be relied on to close properly, and in this is a danger of derailment which may be traced to worn tires. To prevent such action, the spring rail is often planed down where the tire strikes it, as already noted, so that the false flange will clear it. There should also be a flaring opening left at the point, so that the tire flange would be started in before any pressure is put on the spring rail, thus relieving the guard rail. The damage to rigid frogs is of a similar character, but there

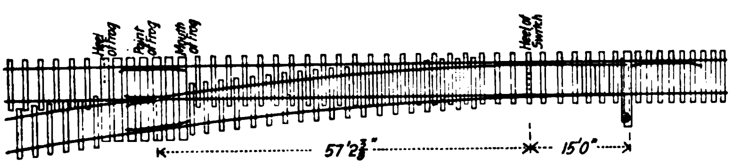


Fig. 66.--Turnout Laid on Ordinary Ties; Boston & Albany Ry.

is less danger of derailment. The swing given to a locomotive with hollow tires when running over a frog causes the gage of track and guard rail to be affected, and disturbs the general line of the frog, necessitating frequent readjustment. The effect of hollow tires on split switches is about the same as on spring rail frogs, there being some danger of derailment, especially when a train trails through. For this reason, the switch rails are kept below the level of the head of the stock rail near the point, as already noted.

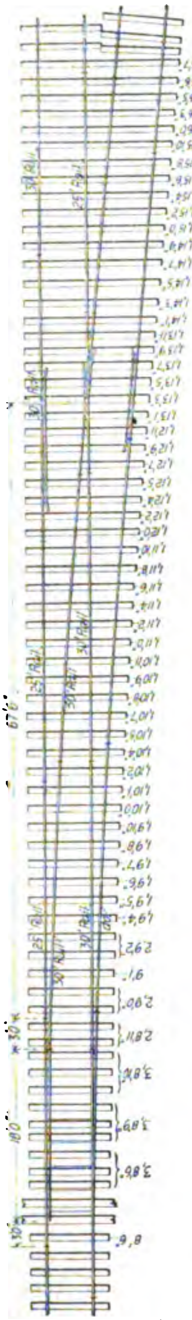
Switch Ties and Timbers.

The rails of turnouts may be laid upon sawed switch timbers or switch ties of varying length, carrying the main and turnout rails, as shown in Figs. 65 and 67, or upon ordinary ties alternating for the two tracks, as in the Boston & Albany Ry. practice, shown in Fig. 66. The former plan looks better, makes a more solid connection between the tracks, and is generally used. The long ties are somewhat difficult to renew, and have generally to be renewed in sets, while the alternated ties give a closer support to the lead rails. On the other hand, it is more difficult to tamp the separate ties to an even and uniform bearing. Switch timbers should be of the same thickness as the ties, and not less than 7 or 8 ins. wide on the

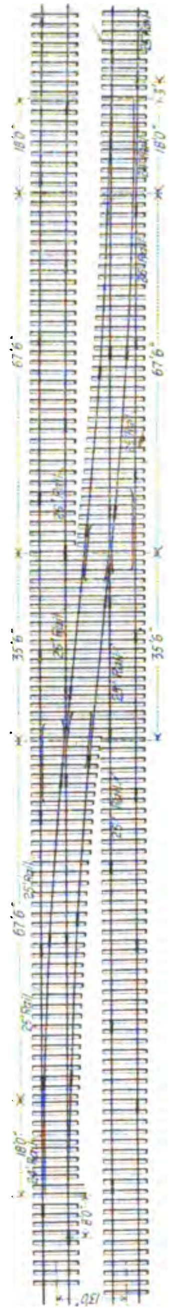
face. Some roads have them 9 and 10 ins. wide, to give a good bearing to the curve lead rails, as the sharp curve makes them liable to cut into the ties along the outer edge of the rail base. It is better to prevent this cutting by the use of metal tie-plates, and great economy has been effected by their use, while they are also frequently used to replace rail braces on turnout curves. The timbers should be spaced about 20 to 24 ins. apart, c. to c., not less than 8 ins. apart in the clear, but the spacing must be varied to fit the rail joints and to get a tie under the frog point, or as nearly under as a yoked frog will permit.

The required length of the timbers is ascertained by taking the distance (in inches) between the tie at the heel of the switch and the tie under the frog point, dividing this by the number of ties to be placed between them, and adding the amount thus obtained to the length of each tie, starting from the heel of the switch. This arrangement, with every timber cut to length, is shown in the Erie Ry. turnout (Fig. 67). Very frequently, however, instead of using a different length for each timber, the timbers are made in groups of the same length to the nearest 6 or 12 ins. This is done by the Southern Pacific Ry., as shown by the dotted lines in Fig. 68, but on that road after the ties are laid their ends are cut off parallel with the sidetrack rail, as indicated, which seems to be entirely unnecessary, involving useless labor and time. This turnout is for a No. 9 spring-rail frog, and tracks 15 ft. c. to c. Where the sidetrack rails are lighter than the main track rails, step chairs or joints must be used to connect them beyond the switch. Switch rails are curved as follows, before being laid: 38 ft. from frog, 11½° curve; 22 ft. to heel of point rails, 1⅛° curve. At each heel joint, one of the angle bars has its flange planed off. The turnout rail is bent (not curved) to the proper angle at the point (A) by means of a rail bender, 16 ins. from the end of the point rail. The point guard rails in front of the switch are 6 ft. long, with 2-in. flangeways, or 4 ft. 4⅛ ins. face to face of rails.

The last long timber should not exceed 16 ft. in length, though for crossovers on double track the middle timbers are often made long enough to take both tracks. A practice sometimes followed is to have a plank about 1 × 10 ins., 16 to 18 ft. long, with the lengths of the several timbers scribed and marked upon it. This is used as a gage in sawing the timbers to length before laying, but it is better to have them sawed to specified lengths at the mill, if this can be done. To ascertain the length of timbers for a three-throw switch, subtract half the length of the standard tie from the length of the switch timber for a single switch, and then multiply the remainder by two. Most roads have fixed tables or bills of material for switch timbers, which are issued to the foremen. The arrangement of ties at track crossings will be found in Chapter 9, under the heading of "Track Crossings." The ties or timbers should be carefully laid on good, well drained ballast, and firmly tamped, especially under the frog, except that where plate frogs are used the ties may be set a little low, or allowed to settle, to allow for the thickness of the plate. This is better than cutting the ties to receive the plate. In Table No. 13 are given examples of bills of material for switch timbers, and on the Lehigh Valley Ry. these bills give the number and length of each timber in consecutive order.



(Turnout for 80-lb. Rails.)



(Crossover for 80-lb. Rails.)

Fig. 67.—Arrangement of Switch Timbers at Turnout and Crossover; Erie Ry.

Fig. 68.—Turnout; Southern Pacific Ry.

TABLE NO. 13.—BILLS OF TIMBER FOR SWITCHES.

Southern Pacific Ry.

No. 9 spring rail frog; tracks, 15 ft. c. to c.; timbers, 7 x 8 ins. or 7 x 9 ins., as ordered; headblocks, 7 x 10 ins. The lengths given are for 8-ft. main track ties; for 9 ft. ties add 1 ft. in each case. The table shows lengths where the longest commercial lengths are 22 ft. and 26 ft.

Commercial length, 22 ft.

No. of pieces.	Length, ft.	ins.	Remarks.
1	16	0	Headblock, 7 x 10 ins.
3	16	0	
6	8	6	
3	15	6	
2	15	0	
2	14	6	
3	14	0	
2	13	6	
2	8	6	
3	13	0	
3	9	0	
3	12	6	Cut from 13 pieces 22 ft. long.
3	9	6	
2	12	0	
2	10	0	
3	11	6	
3	10	6	
3	11	0	
3	9	0	
1	10	6	Cut from 5 pieces 20 ft. long.
1	9	6	
2	10	0	
2	9	0	
1	9	6	Cut from 2 pieces 18 ft. long.
1	8	6	
1	10	0	
61			

Commercial length, 26 ft.

No. of pieces.	Length, ft.	ins.	Remarks.
1	16	0	Headblock, 7 x 10 ins.
3	16	0	
1	8	6	
3	15	6	
3	8	6	
2	15	0	
2	9	0	
2	14	6	
2	9	6	
3	14	0	Cut from 19 pieces 24 ft. long.
3	10	0	
2	13	6	
2	10	6	
3	13	0	
3	11	0	
3	12	6	
3	11	6	
2	12	0	
2	10	0	
2	10	6	Cut from 3 pieces 20 ft. long.
2	9	6	
1	9	6	
1	8	6	Cut from 3 pieces 18 ft. long.
4	9	0	
2	9	0	Cut from 2 pieces 26 ft. long.
4	8	6	
61			

Philadelphia & Reading Ry.

No. 10 spring rail frog; tracks, 12 ft. 1½ ins. c. to c.; all timbers 7 x 9 ins., except those marked (*), which are 8 x 9 ins.

Turnout								Crossover			
No. of pieces.	Length, ft.	ins.	Feet, B.M.	No. of pieces.	Length, ft.	ins.	Feet, B.M.	No. of pieces.	Length, ft.	ins.	Feet, B.M.
5	8	9	230	2	13	3*	159	10	8	9	460
5	9	0	237	1	13	6*	81	10	9	0	474
4	9	3	194	2	13	9*	165	8	9	3	389
4	9	6	200	1	14	0	74	8	9	6	400
3	9	9	154	2	14	3	150	6	9	9	308
3	10	0	157	1	14	6	76	6	10	0	315
3	10	3	162	2	14	9	154	6	10	3	323
2	10	6	111	1	15	0	79	4	10	6	221
2	10	9	113	1	15	3	80	4	10	9	226
2	11	0	116	2	15	6	162	4	11	0	231
2	11	3	119	1	15	9	83	4	11	3	238
2	11	6	121	3	16	0	252	4	11	6	242
1	11	9	62	1	16	3	85	2	11	9	123
2	12	0	126	1	16	6	86	4	12	0	252
1	12	3	64	1	16	9	88	2	12	3	129
2	12	6	131	2	17	0	178	2	16	0	168
1	12	9*	77	2	17	3	181	13	20	9	1,417
1	13	0*	78	.	..	..	...	16	20	9*	1,992
Total				71			4,385	113			7,908

Switchstands.

The switchstand contains the mechanism for operating the switch, and consists essentially of a frame carrying a vertical shaft (of sometimes horizontal for yard switches) with a double target at the top and a horizontal crank at the bottom, the switch-connecting rod being attached to this crank. The shaft is turned by means of a lever hinged to it, the lever normally hanging down, and held by a lug or socket on the stand. When the switch is to be thrown, the lever is raised to a horizontal position and

swung round until it is in position to engage with another lug or notch, turning the shaft and crank and operating the switch. This is the operation of the switchstands shown in Figs. 69 and 71. In some cases the crank is replaced by a bevel gear rack and segment, while in others the lever operates a segmental spur gear at the top or base of the switchstand. In the latter case, the crank shaft and target shaft are separate rods, connected by the horizontal gears keyed to them, the lever being attached to the target shaft. In some yard switchstands a spiral slot on a drum or barrel, with a stud on the switchrod, replaces the crank generally used. With the steady increase in the use of the block system and interlocking plants, there is a more general use of the interlocking system at main line turnouts and yard entrances and in passenger yards. In such cases the switches are operated from levers concentrated in a tower, but the subject of interlocking is too broad to be dealt with here, and only the ordinary switchstands operated by hand are referred to in this chapter. (See Chapter 14.)

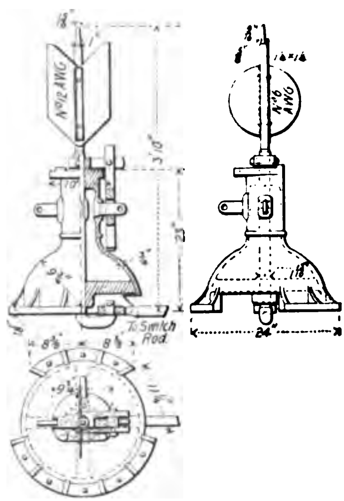


Fig. 69.—Low Switchstand; Illinois Central Ry.

Main line switches, whether interlocked or not, should be connected with distant signals 1,000 to 1,500 ft. distant, according to the situation, conditions of train service, etc. It should not be possible to open the switch for the sidetrack until the signal has been set to stop main line trains and to give a clear signal again until the switch has been set for the main track. This may be provided for by a double-lever switchstand, with levers so interlocked that the switch lever must be fully reversed and the switch rails properly set before the signal lever can be operated. For the reverse movement, the signal must first be changed before the switch can be moved. A single-lever switchstand is sometimes used for the same purpose. The first part of the movement throws the signal to "danger," and the second part opens the switch for the siding. The reverse motion first sets the switch for the main track and then sets the signal at "clear." Where distant signals are not regularly used, they should be used to protect main

line switches on a curve or where the view is so obstructed that the switchstand cannot be seen until the train is close to it. The Illinois Central Ry. places a semaphore signal 1,200 ft. from the switchstand of outlying switches.

The distance from rail to switchstand varies considerably. On the Chicago & Northwestern Ry. it is 6 ft. 6 ins. On the Pennsylvania Lines the standard distance from gage side of rail to center of target rod is 6 ft. 8½ ins. for high automatic stands and 3 ft. 9½ ins. for low stands. Main line switchstands should have target rods 6 to 8 ft. high, so that the targets and lamps will be prominent. Ordinary yard switchstands should be 4 to 5 ft. high, while low ground or dwarf stands may be 2 ft. high. Yard switchstands are sometimes horizontal, as in Fig. 70. Where two or three switches near together open out from a main track connection, the switchstands should be set at varying distances from the rail, so that the targets will not be in line, or should have the targets at different heights, increasing from that at the first switch. A simple device for unimportant yard switches is a drop-lever switchstand (Fig. 51) operated by a lever lying on the headblock. If little used, targets may not be required, and the lever may be secured by a padlock. Such switchstands are sometimes used (but most

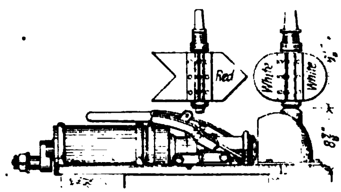


Fig. 70.—Horizontal Switchstand; Norfolk & Western Ry.

improperly) for main line connections. Underground switchstands are used abroad to some extent, and have the advantage for yard use, that they offer no obstructions for men to trip over. One form has an iron box sunk in the ground, with its top flush with the surface. An inverted T rocking lever inside has a stirrup handle at the top, passing through a slot in the cover of the box, and the switch rod is connected to this vertical leg. A heavy weight rolls along the lower leg, and ensures the switch being fully thrown in either direction. Many accidents have occurred through men neglecting to close the switch after a train has entered or left the siding, and various devices for preventing this have been patented, but are of little use. The New York, New Haven & Hartford Ry. at one time had the switch lever placed in a cabin whose door was so arranged that the man had to enter the cabin and close the door before he could set the switch for the siding, and then could not open the door until the switch had been reset for the main track. To prevent hand switches from being thrown while trains are passing, a detector bar (operated in connection with the switchstand) may be used, while some roads require the man to stand 10 or 15 ft. away from the switchstand until the rear car has passed. The hand switchstand may be electrically locked, so that a train cannot pull out of a siding without permission from the signalman or telegraph operator. The use of interlocking plants, however, is the most effective insurance against wrongful operation of hand switches.

The Illinois Central Ry. has three standard sizes of rigid switchstands; 3 ft. 10 ins., 5 ft. 5 ins. and 7 ft. 1⅛-ins. high to the top of the rod (exclusive of the lamp). Where three switchstands come in line at one end of a station, the low stand is used for the first or outer switch; then the medium and then the high stand. Where two come in line, the medium is used for the outer and the high stand for the inner switch. These stands have a white disk and red target, as shown in Fig. 69. On the high stand the disk is 17⅛ ins. diameter, of No. 16 A. W. G. steel; the red target is 30x12 ins., of No. 12 steel. The Norfolk & Western Ry. high stand is 7 ft. 5⅛ ins. from the tie to the top of the rod, and has an oval white target ⅛-in. thick (No. 10 iron) 12x8½ ins., made in two pieces, flanged and riveted; the red target is 24 x12 ins., rectangular, with a 6-in. fishtail notch. The stand has switch rods 1½ ins. diameter, target rod ⅞-in. square, and a throw of 3¾ ins., the distance from center of shaft to center of pin being 2⅝-ins. The lamp has 5⅝-in. lenses. The medium stand is 3 ft. 11⅞-ins. high to the top of the shaft. The medium, low and pony (horizontal, Fig. 69) switchstands have white oval targets, 6 x 10 ins., and red targets, 6 x 12 ins. The Great Northern Ry.

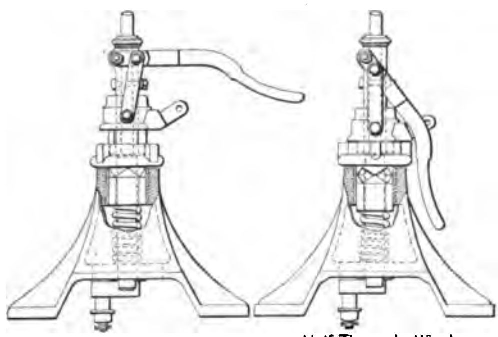


Fig. 71.—Ramapo Automatic Switchstand.

uses a high stand 8 ft. 10 ins. high to the top of the lamp fork, with a white target 12 ins. wide, on which is painted a 9-in. red disk. The target for the turnout may be shaped to indicate to which side the switch leads. On double track the back of each target may be painted black.

The switchstand is carried on one or two long ties, called the headblocks, so as to be kept immovably fixed in relation to the switch, but for high switchstands the shaft carrying the lamp and target is frequently supported by collar bearings on a vertical braced post or a set of three or four inclined rods, the post or rods being fitted to a framed foundation independent of the headblock. In this way the lamp is relieved from some of the shock and jar incident to the operation of the switch. The switchstand should be firmly bolted to well tamped headblocks, and no lost motion should be allowed, while the working parts should be kept true, clean and well oiled.

To allow for trains trailing through a closed switch without injury to the switch, an automatic switchstand is frequently used. In the Ramapo switchstand, Fig. 71, the upright rod has a sliding sleeve, with a clutch connection and spring. This gives a direct and rigid connection when

worked by hand, but when worked automatically by a train, the pull on the connecting rod (as the wheels engage with the switch rails) turns the lower part of the shaft, compressing the spring and pulling down the lower jaw of the clutch so that it can turn without affecting the upper part of the shaft, which is locked to the switchstand. The spring closes the clutch connection and returns the switch to its normal position as soon as the pressure is removed from the switch rail. There are various styles of automatic switchstands, generally having a combination of clutch and spring, but in the Weir switchstand the clutch is done away with and two horizontal springs connect with the lever casting on the shaft. If a train in making switching movements should trail partly through a closed switch and then back up, the train would be split, the cars behind the switch keeping to the sidetrack, while those in front would take the main track. This would probably result in derailment, with damage to cars and switch, and such an accident would indicate neglect and carelessness on the part of the train crew and switchmen. To provide against this, however, switches have been arranged to remain in the position to which they are thrown by the wheels, but this is a dangerous plan and rarely followed. The automatic switchstand may be made so that the switch can be trailed through from either track when set for the other track, or so that it will be locked when set for the main track. In the latter case, a train trailing through from the sidetrack would break the connections, and show that the switch had been misused, as it is a dangerous practice to allow trains to thus run through a switch set for the main track. The automatic switchstand is safer than the automatic switch, already described, Fig. 51, as the latter can have the lever thrown even when the switch rails are not fully thrown, owing to obstruction between the switch and stock rails. In the automatic switchstand this cannot be done. While there are certain places where the use of automatic switchstands is permissible, and while they are quite generally used, the best practice is to adopt a rigid stand, as in Fig. 69, and to forbid the running of trains through closed switches.

Switch Targets.—The targets are usually of sheet iron (No. 10 to No. 16 American wire gage) of square, diamond, circular or other shape. The two targets for the two tracks governed by the switch should be of as distinct shapes as possible, and should be kept clean and well painted, as in gloomy weather, or with smoke and steam blowing across the track, an engineman may easily mistake what he can see of a dirty red square to be a dirty white disk. On the New York Central Ry. they are painted in April and October of each year. The stands for three-throw switches should have targets indicating for which track the switch is set. The targets should not be too large, or they will be a danger to brakemen hanging on the sides of the cars, and some of the horizontal arrow targets are very objectionable in this respect. On low stands, or pot signals, the targets may be attached to the sides of the lamp case, or to a rod rising above the lamp. As to the color of the targets, plain red and plain white are usually the most distinctive, and can be seen at the greatest distance. A black spot on the white does not make it any more readily distinguishable, except against snow. Any white on the red tends to make it appear pink and consequently less bright and prominent, but at a short distance and with a dingy background, the combination may be more prominent than the plain red. Red and white

are most commonly used, though some roads use green and white for the targets of yard switchstands and green targets for the distant signals. As vermilion paint is expensive, a bright red chromate of lead paint may be used and applied more frequently, and the colors are practically the same after a little exposure. If the switchstands are painted white, or whitewashed, their positions will be more easily seen by the engineman, and the same applies to the signal posts of block signals. Enameled iron targets have been tried with good results on the Grand Trunk Ry.; they do not catch the dirt, do not fade and are easily cleaned. The high stands for main track switches on the Richmond, Fredericksburg & Potomac Ry. have a circular target for the main track, and a fixed red and white arm like a semaphore blade for the sidetrack. On the Pennsylvania Lines West of Pittsburg, the main line switchstands are connected with standard semaphore signals, the running face of the blade being yellow, with a black band; and the back face white, with a black band. This is good practice in view of the fact that the semaphore is practically the standard form for block signals, and the same practice should be followed where interlocking plants or distant signals are used.

Switch Lamps.—The switch lamps should be of good construction, sheet steel or galvanized iron being usually preferable to tin. They are either square or round, and have generally hinged doors, which are preferable to slides. In some cases there is no door, the oil pot being removed, put in and taken out from the bottom of the case, while in some of the round lamps the top is hinged to swing open. Side doors and slides should be air tight, and the ventilating openings so protected that the light cannot be blown out by the wind. In the Adams & Westlake lamp, the Watts upper draft system is employed, the air supply being taken above instead of below the flame, as at A, Fig. 72. Kerosene is generally employed for the lamps, and chimney glasses are not often used. There should be a peep hole and wick raiser in the outer case, so that the lamp can be inspected and trimmed without opening the door. A spring bottom is also sometimes used to prevent the wick from being shaken down by the jarring of the switchstand. The lenses should be of ample size and good design, so formed as to throw a direct beam of light of the greatest intensity, and not a diffused light. The lenses may be of plano-convex form (flat at the back and spherical on the face), but the best form has the back cut in concentric corrugations, as shown at A and B, Fig. 72. In some cases, however, the corrugations are on the face of the lens, as at C, Fig. 72. The ordinary size of lens is 4½ to 6 ins. for semaphores and main line switchstands, and the larger size is preferable. A diameter of 8 to 8⅜ ins. is sometimes employed for lamps at signals, tunnels and crossings. The lamps for yard switches may use 4-in. or 4½-in. lenses; and those for dwarf signals, 3-in. lenses; while backlights may be 2 ins. diameter.

To ensure the lamp being in proper position on the switchstand, the socket or fork should be so shaped that the lamps can be put on only in one position. If a socket on the lamp fits on the top of the vertical shaft of the switchstand, the top should be rectangular instead of square, or one corner of the socket may be filled up to fit a chamfered corner of the rod. The lamps should be kept clean, in good repair and properly trimmed, the lenses especially being wiped free from grease and dirt. The wick should rarely

be cut with scissors, but the crust on its top may be removed by the fingers or a match stick. The light should be turned down as soon as lighted, and then gradually turned up to give the proper size of flame, being watched for a few moments to see that it burns steadily and does not flare or smoke. When the light is extinguished the wick should be turned down to prevent waste of oil. If the lamps are carried lighted from the section house they should be examined after being put in position on the switchstand. The filling and trimming of the lamps should be done on a shallow zinc-lined

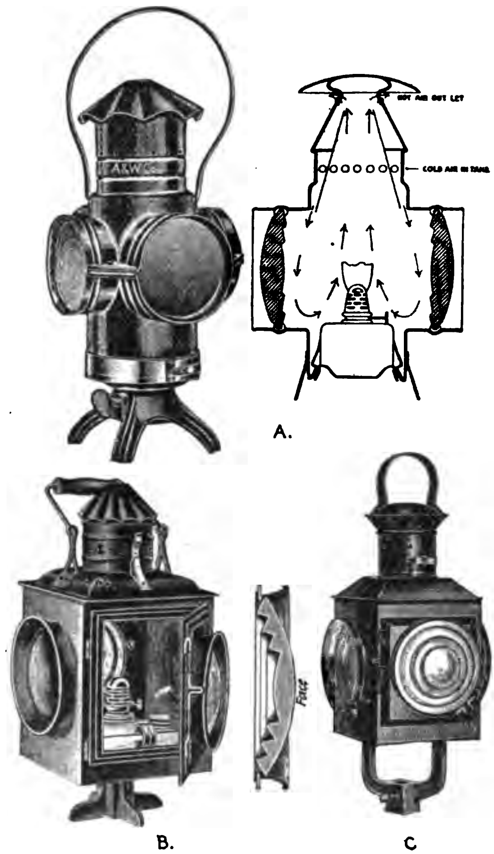


Fig. 72.—Switch Lamps.

tray or shelf with raised edges to prevent waste of oil, and the oil cans may be set on a shallow tray filled with sand, to prevent the floor from getting greasy. The lamps are usually kept lighted from sunset to sunrise, and during foggy weather.

Red and white are the colors most generally used for switch lights (Fig. 51), while some roads use green and white for yard switches. There is, however, a strong tendency towards the use of green instead of white as the

clear signal for main track. This is a very desirable change, as station and street lamps are liable to be confused with white signal lights, especially at yards in towns. Red and green are therefore frequently used for main line switchstands, the lamps showing a green light in each direction when the switch is set for the main track and a white light in each direction when it is set for the side track. On some roads, however, the light is shown only in the facing direction, the lamp having only two lenses. This is specially the case on double track. (See Chapter 14.)

CHAPTER 8.—FENCES AND CATTLEGUARDS.

Fences.

The numerous styles of right-of-way fencing in use by railways are due to local conditions, and the varying ideas of engineers and manufacturers, while some States have laws specifying the style of fence more or less in detail. The height should be at least 4 ft. 6 ins., and 5 ft. is preferable where cattle are kept.

Wooden Fences.—Rail and board fences are now the most common forms of wooden fences. In the former, the posts are slotted to receive the ends of the rails, having the ends flattened to fit into the slots, where they either lie loosely or are secured by pins through the post. The board fence is by far the more common, and has flat boards or planks nailed to the posts. Oak, tamarack, locust, cedar and chestnut are used for fence posts, the two latter being the more durable. They are usually 7 to 8½ ft. long, 6 to 6½ ins. diameter at the large end, and 4 to 5 ins. at the small end. They should not be split, but left round, stripped of bark, and may be pointed if they are to be driven, but this is not necessary where they are set in post holes. It is best to put the larger end downward. The posts should be not less than 2½ or 3 ft. in the ground, and may be driven by mallets or a small pile driver mounted on wheels; or they may be set in holes made by long-handled shovels or post-hole augers or diggers. If the hole is 24 ins. deep and the post is driven 12 or 18 ins. deeper and the earth then well rammed and tamped into the hole, the post will be very secure. The tops should be cut off square at a uniform height above the ground, the height being gaged by a stick having a flat board at the bottom. The posts are usually spaced 8 ft. c. to c. If the ground is heaved by frost and throws the posts out of line and partly out of the ground, as is specially the case in clay soil, the soil should be dug away, the posts redriven and the earth tamped in again. Fences have sometimes to be built on rocky or swampy ground where posts will not hold, and in such cases the posts may be mortised into sills 4 ft. long, made of old ties cut in half, and secured by braces nailed to the top or side of the sill and back or side of post. Rough A-frames made of posts may also be used.

The boards are generally of pine, hemlock or other cheap wood, 16 ft. long, 1 or 1¼ ins. thick, and 6 to 12 ins. wide, 6 or 8 ins. being preferable. They should all be of the same size, the bottom boards being placed closer together than the upper ones so as to stop small stock. The boards are placed on the field side of the posts, and each is secured by three or four 10

or 12 penny (4-in.) nails, while occasionally the posts are notched or boxed out ⅛-in. for the boards. If all the joints come on the same posts, a batten, 1 × 6 ins., may be nailed to cover them, but in general the joints are broken, and come on alternate posts. Five boards are usually sufficient, and in some cases a cap board is laid flat on the top of the posts. When this is done, the top board may be omitted, but the standard board fence of the Michigan Central Ry., Fig. 73, has both cap and top boards. It is not often that the bottom board is laid on the ground, as shown here, but this is the legal railway fence in Michigan. The Baltimore & Ohio Ry. uses two bottom boards, a top board, and two diagonal boards across the intervening space, with a batten at the intersection.

Wire Fences.—These are extensively used, on account of their efficiency, safety from fire, and small amount of maintenance required. They are of two kinds: strand fencing and woven fencing. The former consists of independent horizontal strands of plain, twisted, ribbon or barbed wire, weighing about 345 lbs. per mile, or 6½ lbs. per 100 ft. The posts may be 8 to 16 or 20 ft. (or even 24 to 33 ft.) apart, and four or more wires may be used as required, the lower wires having a closer spacing than the upper ones. Some makers are using a high carbon wire of exceptional strength,

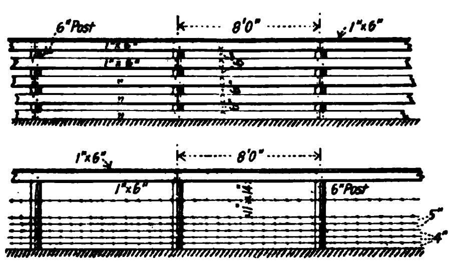


Fig. 73.—Board and Wire Fences; Michigan Central Ry.

enabling the posts to be set farther apart. Thus a No. 11 wire of 0.4 to 0.45% carbon has a breaking strength of 1,800 lbs., as against 1,000 lbs. for a common wire of 0.1% carbon. Barbed wire fencing is objectionable in many ways, and its use is prohibited in some States, while many railways as well as landowners are opposed to its use. With this wire, and in fact with almost any fence of longitudinal wires, a top board should be used so that horses and cattle may see the fence more clearly and so be prevented from running against the wire and being injured. Some roads cut the tops of the posts at an angle of 45° and spike on a top board or rail 2 × 4 ins. The standard wire fence of the Michigan Central Ry., Fig. 73, has six wires, a top board and a cap board. At the starting end of each length of fence, the wires are secured to a strongly braced anchor post, and in order to allow of taking up the slack and sag of the wires, their free ends are attached to spools in an iron post or to some other adjustable fastening by which the wires may be wound up and tightened. To prevent the wires from pulling the posts over, some of the posts (say, at every fifteenth or twentieth panel of 15 ft.) must be braced. The braces may be of plank or a 3 × 5-in. stick having one end let into the top of the post, and the other end let into the

next post at the ground line or into the top of a stake driven into the ground between the posts. Posts may also be braced by a stout wire wrapped around the top of the post and carried down to and wrapped around the two adjacent posts at the ground line. Gate, corner and end

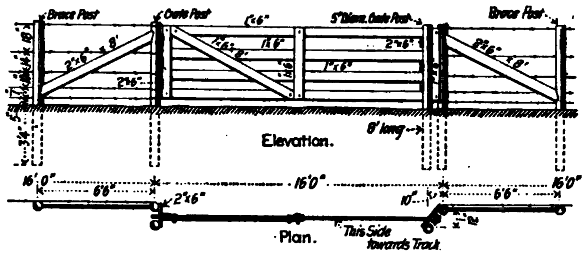


Fig. 74.—Wire Fence and Farm Gate; Fremont, Elkhorn & Missouri Valley Ry.

posts must also be well braced and anchored to ensure their maintaining a vertical position. The strands are usually attached to the posts by wire staples (70 or 75 per lb.), and for long panels they may be stapled to a batten at the middle of each panel, so as to keep the wires evenly spaced and prevent them from sagging. Hogs are very difficult animals to turn, and sheep will often get through a barbed wire fence that seems impassable. A special fence for holding hogs may have a bottom board, then two boards, and then two, three or four wires and a top board. The close (4-in.) spacing

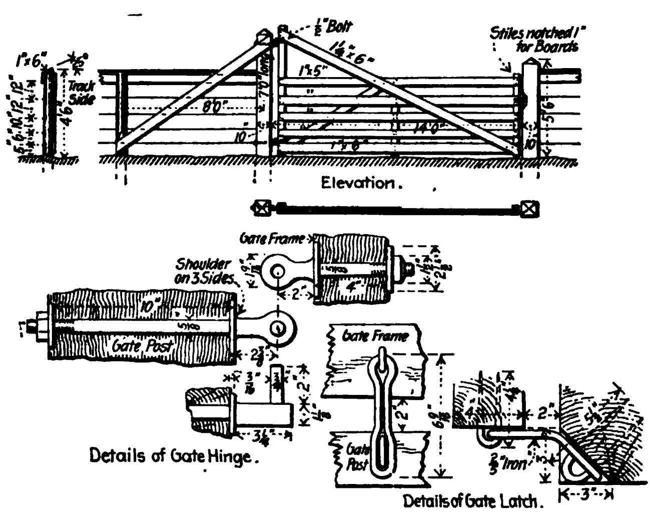


Fig. 75.—Wire Fence and Farm Gate; Canadian Pacific Ry.

of the bottom wires of the Michigan Central Ry. fence, Fig. 73, is to prevent sheep and hogs from getting through.

The standard wire fence of the Fremont, Elkhorn & Missouri Valley Ry., Fig. 74, has 16-ft. panels, with five lines of barbed wire, spaced 5, 7, 10, 14 and 18 ins., and has no top board. The fence of the Canadian Pacific Ry., Fig. 75, has four wires, a top board, and an inclined cap board. The posts

are of round cedar, not less than 5 ins. diameter at the top, straight and peeled. The wire has barbs not less than 6 ins. apart, and is stapled to the posts. The boards are nailed to each post with six 4-in. cut nails, and braces are put in at intervals of 300 ft., notched 1¼ ins. into the posts and secured by 40-penny nails. Fig. 76 shows the styles of fence used by this road on rocky ground, the vertical post style having four wires, and the A-frame style, five wires. The wire fence of the Louisville & Nashville Ry., in Kentucy, has posts 7 ft. long, 10 ft. c. to c., with seven wires, spaced 4, 4, 6, 8, 10, 12 and 12 ins. The three lower wires are of barbed cattle wire, except where there is danger to stock, in which case the two top ones are of plain ribbon wire. The estimate for one mile of one line of this fencing is as follows:

2 plain ribbon wires	6.66 lbs. per 100 ft.	704 lbs.
2 barbed cattle wires	7.14 " " 100 "	754 "
3 barbed hog wires	7.69 " " 100 "	1,218 "
Staples		49 "
Posts, 10 ft. apart		528
Bracing, 1 x 6-in. yellow pine boards		440 ft.B.M.
Labor		$105

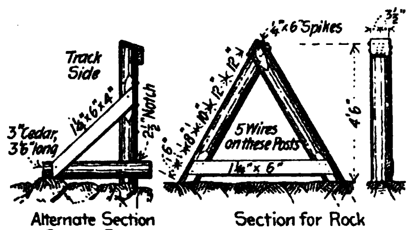


Fig. 76.—Fence Posts for Rocky Ground; Canadian Pacific Ry.

Woven wire fencing has now largely superseded line wire or strand fencing, and is very extensively used, being adopted as standard by many important railways. It is usually delivered in 40-rod rolls, and can be erected rapidly and at comparatively small expense. The McMullen fence, Fig. 77, resembles poultry netting of very large mesh. It could only be made of light wire on account of the twisting required, while the twisting injured the wire so that the fence did not prove very satisfactory for railway purposes, and it has been superseded by woven fences with rectangular mesh and heavier wires. The first of these, was the Page fence, Fig. 78, composed of longitudinal wires (variously spaced according to requirements) and vertical stay wires about 12 ins. apart, the latter being twisted round the former at each intersection. The special feature is that the longitudinal wires (of hard steel) are first coiled round a ¾-in. rod, forming spiral springs, which are then straightened out and connected by the vertical wires. The effect of the coiling is to give the wires a spiral twist, so that any tendency to slack, sag or tighten is taken up by the spring of the wires. This gives the fence elasticity enough to resist stock pushing against it, and to throw down an animal that may run against it. The wires are usually No. 7 or No. 9 for the top, No. 9 for the bottom, No. 11 for the intermediate and No. 14 for the vertical wires. The railway fence is usually 4 ft. 10 ins. high. It is deliv-

ered in rolls of 20 to 40 rods, weighing 11 lbs. per rod, and the panel length may be 30 ft., but 16 ft. is preferable. In erecting the fence, a full roll of 40 rods is set up, and given a strain of 5 tons by means of a stretcher, so that strongly braced end posts are needed. The vertical stays extend only to the second wire from the top, short stays connecting the two top wires, so that animals leaning over the fence will only depress the top wire. The Lamb fence is very similar to the above, but has the stays secured to the longitudinal wires by a tie wire at each intersection. This enables heavier stay wires to be used. In the American fence, the longitudinal wires are not coiled, but provision for contraction and expansion is made by giving the wire a slight kink or curve at each point of intersection with the vertical stays and between these stays. Another feature of the fence is that the stay wires instead of being continuous for the full height of the fence, only extend from one longitudinal wire to another, the ends being wrapped around each wire. The standard railway fence, which is in use on a number of important lines, is 49 ins. high, with nine wires spaced 4, 4½, 5, 5½, 6, 7, 8 and 9 ins. apart, connected by vertical stays 12 ins. apart (or sometimes only 6 ins.). The top strand is of No. 7 wire; bottom strand, No. 9; other strands, No. 11, and stays No. 12. The panel length is usually 16 or 16½ ft., and the fence weighs about 9¼ lbs.

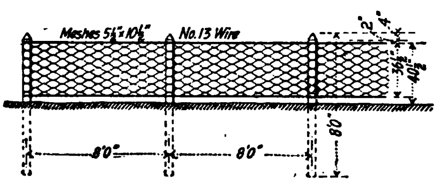


Fig. 77.—McMullen Woven-Wire Fence.

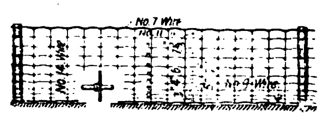


Fig. 78.—Page Woven-Wire Fence.

per rod, or 12 lbs. with 6-in. stay spacing. The Elwood fence has horizontal strands of twisted wire cable, connected by diagonal stay wires woven together and to the cables, forming a diamond mesh. The mesh is made smaller for a height of 34 ins., and is subdivided by two longitudinal wires between the lower cables, so as to effectively turn small stock. For station grounds, this is made of small mesh, 30 to 58 ins. high, with cables 4 ins. apart.

The Jones wire fence consists of 8 to 10 horizontal galvanized steel wires, spaced from 4 to 5 ins. apart at the bottom, to 8 and 10 ins. at the top, the height being 4½ to 5 ft. The posts are 16½ to 24 ft. apart, and between them are vertical stays of No. 7 hard steel corrugated wire, about 30 ins. apart, secured to the longitudinal wires by special flexible clamps. This fence is built in the field, and will weigh about 13 lbs. per rod. The Barkley & House fence has seven No. 9 galvanized wires, with galvanized wire stay guards or flat spacing pieces between them. These connect each pair of wires and are not continuous from top to bottom, being staggered. The flat pieces are easily bent by compression or side blows, pulling the fence out of shape. The ends of the wires are in stretchers in the straining post, and the wires can be tightened up at any time, as they are not stapled tight to the post. The Betts fence consists of six No. 11¼ galvanized wires stapled

to pine pickets about 1 ft. apart, the pickets making a close fence and preventing animals from hanging their heads on it. It is delivered in rolls of 100 ft. and is fastened to posts 12 to 14 ft. apart. In strand fences it is often necessary to take up the slack or sag of the wire, and this cannot always be done by the end stretchers in the anchor posts. One plan is to loop vertical stays to the wires, these being attached by a special wrench. Another plan is to wind up the slack on a tightener, hitched to the wire, a lug preventing the device from unwinding. Such devices are shown in Fig. 79. The Jones stay wires, extending the full height of the fence, can be applied to old and new fences, and have already been mentioned. All wire fences are liable to corrosion by the smoke and gases from the locomotives, this being more particularly the case near yards.

Metal fence posts are slowly coming into use, and many of them are of ⅛-in. steel plate, 7 or 8 ft. long, pressed to form a post of circular or V-sec-

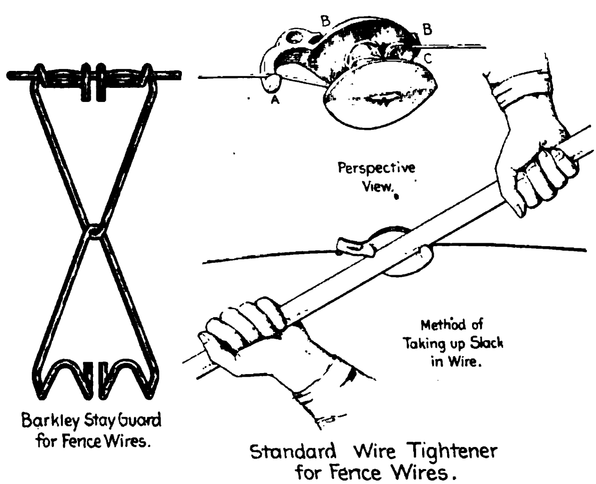


Fig. 79.—Fence Wire Tighteners.

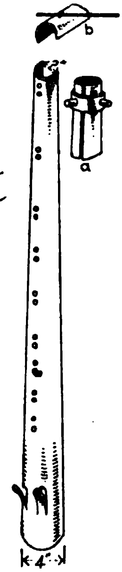


Fig. 80.—Steel Fence Post.

tion, with holes, slots or notches for the wires or staples. Some of these posts can be driven without post holes being dug, a temporary cap being put on to receive the blows of the maul. The Avery post, Fig. 80, is of semicircular section, tapering to the top and having prongs stamped out at the bottom. For end, corner and brace posts, two line posts are set a few feet apart and fitted with collars having studs to fit a horizontal brace of gas pipe, as shown at "a." The method of attaching the wires, by staples fitted into the slots is shown at "b." Light posts of steel angles, tees or tubes are used for lawn fences at stations and similar posts of larger size, secured in vitrified clay bases by cement filling are used for right-of-way fences, track signs, etc. The Union Pacific Ry. has made some use of concrete posts in timberless regions. The line posts are 4×5 ins., and 16 and

54 cts., respectively. Several of these are made at a time, the moulds filling the bottom of a box in which the concrete is dumped. The concrete is composed of about 1 part Portland cement and 3 parts clean, sharp sand. Four two-wire cables of No. 10 wire are embedded in each line post and eight in each corner post. Holes are cored for fence clips and gate irons.

Gates.—Fence gates should be not less than 15 ft. wide in the clear, with gate posts in addition to the end posts of the fence. The gate shown in Fig. 74 slides back for half of its length and then swings round, while some gates slide back for their whole length, parallel with the fence. An ordinary swinging gate is shown in Fig. 75, and this is well supported against drooping by means of the long brace. Iron-framed sliding and swinging gates are extensively used, and many forms of these have a framing of 1½-in. gas pipe, with wires or netting attached to the frame. Gates should be strongly built and well hung on strong hinges. It is a good plan to hang the gates so that they will close by their own weight after having been opened, as farmers are frequently very careless about the gates, but even if made in this way there is a liability of their being propped open. A sheet iron sign, lettered "Close the Gate" may be attached to the gate. Trackwalkers should be on the lookout for open farm gates, and report any that may be habitually left open, as accidents have frequently been caused by cattle straying onto the track through an open gate, and in such cases a country jury may award damages to the farmer, in spite of the fact that the railway was properly fenced and the farmer himself was really responsible for the accident.

Walls and Hedges.—In districts where field stones and boulders are plentiful, dry rubble walls are sometimes built, but as a rule they are not very stable and soon get more or less broken down. Hedge fences are rarely seen in this country, and have the objection of taking up considerable space, and rendering an adjacent strip of field land useless on account of theshade, though they are sometimes considered desirable near cities for the sake of appearance. The Pennsylvania Ry. has some hedges of osage orange, but they are thinner and smaller than the dense and almost impenetrable hedges characteristic of English railways. Hedges are sometimes used as snow breaks, for which purpose the Russian olive is very satisfactory, and will survive heat, cold and drought. Honey locust, barberry or California privet may also be used for both right-of-way and snow fencing. The best English hedge fences are made of thorn quicks, about three years old, which are planted in November or December. The ground is well dug by hand, and the quicks are generally planted in a single row, about 4 ins. apart, but are sometimes staggered in two rows 6 ins. apart. In about 8 years, when the stumps are 1 to 1¼ ins. diameter, the hedge is clipped to the required height, and afterwards it is trimmed about 12 ins. each year. They thrive best in heavy land, and are usually failures in light gravelly or sandy soils. In autumn or winter the ground is turned over for about 2 ft. on each side, to prevent damage in case of sparks setting fire to grass on the slopes, and this is also beneficial in giving air to the roots.

Station and Yard Fences.—Brick walls and high board fences with vertical or horizontal boards placed close together, are frequently used at station yards. Picket fences or neat (and more or less ornamental) iron railings or

fences are often used at passenger stations, around the grounds, or to prevent persons from crossing the tracks, especially where there are separate tracks for through and local trains. A picket fence may have posts 5 × 7 inches., 10 ft. apart, with two triangular rails (cut from a stick 4 × 4 ins.) let into V-shaped notches in the posts. To these are nailed pickets, 1 × 3 ins., or 2 × 2 ins., with pointed tops, the pickets being 2½ to 4 ins. apart. The Pennsylvania Ry. uses a fence between tracks at way stations, having pickets 1⅝ ins. square, 4 ft. long, 6 ins. apart, on rails 3 × 3 ins., the ends of which rest in iron sockets attached to the posts, so that the panels can be lifted out when track repairs are going on, or to allow room for attention to hot boxes or the running gear of trains standing at the station. The posts are 4¼ ins. square, 10 ft. 1¾ ins. apart, c. to c. A neat iron fence between the tracks may be 4 ft. high, with two rails ⅜ × 1¼ ins. and pickets ½-in. square, 5 ins. apart, with ornamental tips and spacing pieces, made with

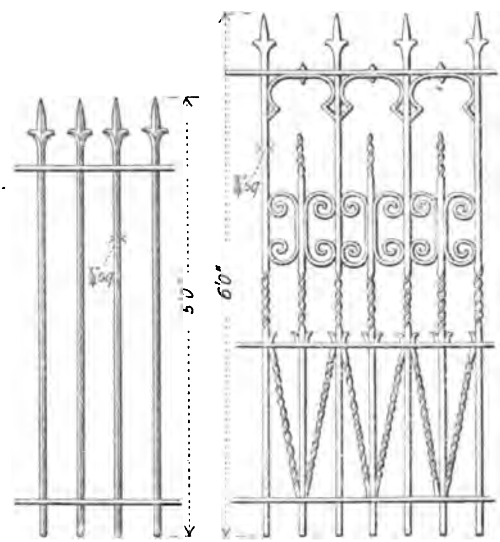


Fig. 81.—Iron Fencing for Stations.

removable panels. All fences between tracks should have gates for the use of employees, the gate having a spring lock, which is opened by a button or knob not readily found by the reckless passenger who tries to cross the tracks. Two designs of iron fence used in railway service are shown in Fig. 81. For station grounds, a fencing of horizontal ribbon wire carried in notches in flat, angle or T-iron posts, is very generally used. The posts have back and side braces at intervals. Horizontal railings of rods or gas pipe in iron or wooden posts are also used, and woven wire fencing is also used for the ornamental grounds which so many railways are now forming at stations. Expanded metal is also used for the same purpose, and for high right-of-way fences in suburban districts.

Snow Fences.—The style of fence to be used on any road depends upon the topography and the amount of the snow. In prairie country these

fences are of great importance, as that is often the most troublesome country in which to deal with snow, especially if the track is raised but little above the normal surface. The fences may be either permanent or portable, the latter being made in sections and having portable braces, so that they can be taken down and piled in stacks when the winter is over. The permanent fence should be at least 50 ft. from the track, to allow for the slope

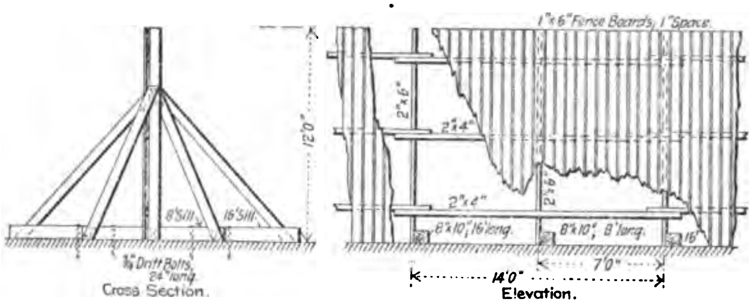


Fig. 82.—Permanent Snow Fence; Canadian Pacific Ry. (Winnipeg Yard).

of the drift, and may be 6 to 8 ft. high, with eight or ten boards. If there is no room for this on the right of way, then the portable fence may be used, having the advantage that it can be set when needed, and that it does not permanently obstruct the view. The permanent fence shown in Fig. 82 is that used by the Canadian Pacific Ry. at division yards, etc., and has vertical boards 1 × 6 ins., 12 ft. long, set 1 in. apart. The permanent snow fence shown in Fig. 83 is used by the Fremont, Elkhorn & Missouri Valley Ry. on its right of way. In Fig. 84, is shown the movable fence of the railway, and is a good example of its type. The sections are 16 ft. long, and the braces

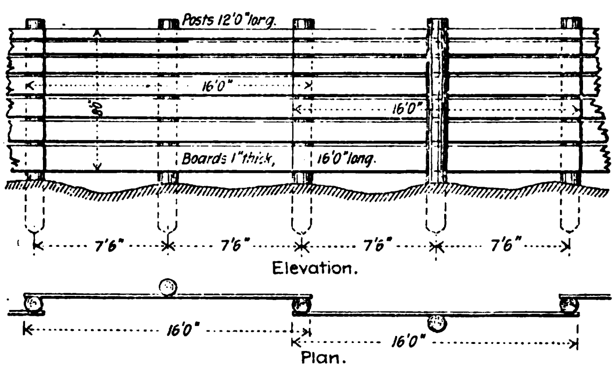


Fig. 83.—Permanent Snow Fence; Fremont, Elkhorn & Missouri Valley Ry.

and stakes are pivoted by carriage bolts, so that when taken up in the spring the panels can be folded flat and piled on the ground. A similar fence on the Boston & Maine Ry. has two posts intersecting and pivoted, with a cross piece connecting their feet. The panels are set a panel length apart, the fence side facing the track, and the intermediate spaces are filled

by loose panels made of planks nailed to two battens. These panels rest against the rear posts of the folding panels, and slope away from the track.

On the Minnesota Division of the Northern Pacific Ry. the greater part of the snow fencing is 9 ft. high, posts 8 ft. apart, with 8 boards 1x8 ins., and 6 ins. apart. There is also a considerable quantity of tight-board fence, 8 ft. to 10 ft. high, which is found to be by far the most effective in heavy snow. The portable snow fence is of the "saw-buck" pattern, with legs 2 × 6 ins., bolted 2 ft. from the top, with a spread on the ground of 5 ft. 8 ins.

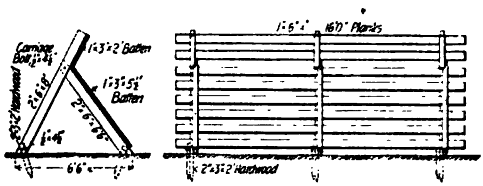


Fig. 84.—Portable Snow Fence; Fremont, Elkhorn & Missouri Valley Ry.

The boards are spaced as in the permanent fence. This fence is fastened to stakes driven in the ground. On one part of the Boston & Maine Ry., permanent snow fences are built down the slopes of the cuts, about 90 ft. apart, alternating on opposite sides of the cut, and placed at right angles to the direction of the prevailing winds which tend to fill the cuts with snow. They serve admirably to prevent snow from drifting across the tracks, but the portable fences would answer the purpose equally well and be less objectionable in appearance.

If the movable fence is used as an auxiliary to a permanent fence it may be placed 100 ft. beyond the latter, or where required to break the force of the drifting snow, the eddy formed by the wind causing the snow to be deposited on the field side, as in Fig. 85, while beyond is the secondary drift. Landowners may demand a small rental for the right to put up this fence in the winter. When the first drift is as high as the fence the snow will blow over, and the fence may then be placed on top of the drift. If it becomes buried in the snow, a wall may be built of blocks of snow, wide enough for

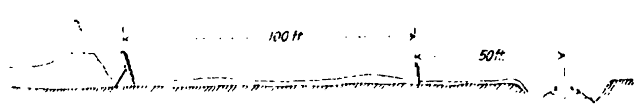


Fig. 85.—Position of Permanent and Portable Snow Fences.

stability and 6 or 8 ft. high. Many Western roads prefer this plan to the use of movable fences, employing extra gangs to build the snow walls, but work of this kind is usually very hard, being carried out during the severe cold and often in the face of a high wind and blinding snow. The snow fences should extend beyond the ends of cuts and then flare in gradually towards the track, so as to protect the cut from drifts caused by winds blowing at an angle to as well as directly across it. If they are not extended far enough, a drift may be formed by a wind blowing obliquely through the cut, and cause a derailment, the engine or snow plow first striking one side

of the oblique drift. The Canadian Pacific Ry. finds the best and cheapest snow fence to be made by setting 8-ft. slabs 12 to 18 ins. in the ground, 75 to 100 ft. from the track. The big ends are placed in the trench, touching one another, which leaves the fence a little open at the top. The cost is about $4 per 100 ft., it is easily moved, and there is no trouble from its being blown down. This road also follows an excellent plan in widening out cuts to give very flat slopes, using the material excavated to form permanent snow banks or fences a little distance from the edges of the cuts. Rows of small balsam, cedar or small evergreen trees, 8 ft. apart, staggered in two rows, the nearest row being 100 ft. from the track, make good snow fences or snow breaks, but their use is not generally practicable. The Russian olive and certain other bushes make good snow hedges, as already noted.

Cattleguards.

Where highways are crossed at grade, a cattleguard is usually placed across the track at each side of the road, with wing or lateral fences extending to the main fences, to prevent cattle from straying onto the track or right of way. They are also used to some extent at the approaches to bridges, tunnels or deep cuts. The cattleguard is placed some distance from the bridge, and the fence is carried along on each side to the abutments or under the first span. At tunnels, the cattleguard is placed near the mouth of the approach cut, and the fence is carried along the cut and over the portal. For deep and narrow cuts the cattleguard is placed near the mouth of the cut.

It is not as easy to turn cattle as might be supposed, and very generally they will become accustomed to the guards and find a way to cross them. If straying along the road they will sometimes spend considerable time in trying the guards, either from a desire to wander or to reach a tempting patch of grass or hay. Hungry cattle are especially venturesome. Some cattle are inveterate wanderers, and will cross almost any form of guard, even as others are inveterate fence breakers or jumpers. If being driven they will often either run blindly into or over the guard, and the length of the guard should be sufficient to deter them from jumping. Hogs and sheep are difficult to stop, and are very persistent in their attempts to reach forbidden ground. If cattle are standing up when struck by a train there is a good probability of their being thrown clear of the track, but if they are lying down a derailment is almost inevitable. The killing of cattle is a troublesome feature, especially in the west, where so much land is unfenced, both on account of the liability of injury to trains and passengers, and the amounts involved in paying for cattle (the value of the animals being usually put at a maximum). It does not seem reasonable, however, to hold the railway company alone responsible for the killing of cattle, as is usually the case, and not to hold the owner responsible for not fencing his land or for allowing his cattle to stray in such a way as to endanger the safety and lives of railway passengers. The trains have a right on the track, but trespassers and cattle have no right, and this should be recognized.

The cattleguard should be considered as a part of the fence, and not a part of the track, and this distinction puts the pit cattleguard out of the

question. Cattleguards may be divided into two general types: pit and surface, the latter of which is now most generally used.

Pit Cattleguards.—The pit guard consists of an excavation in the roadbed, the full width between wing fences, or about 12 ft. wide in the clear, 5 to 10 ft. long (lengthwise of the track), and 30 to 36 ins. deep below base of rail. The pit is often entirely walled up with timber or masonry, but the ends should be left open to provide for drainage. The rails are carried across the pit upon stringers, or upon crossties laid upon the stringers. In the latter case, shown in Fig. 86, the edges of the ties should be beveled off (except at the rail seats) for about 4 ins. in depth of a tie 6 ins. thick, so as to afford but an insecure footing to cattle attempting to cross. This has the objection of being liable to cause the animal to slip through while trying the guard, so that it could not escape and would probably cause the wreck of the train. The pits are rarely made large or deep enough to allow an animal to fall

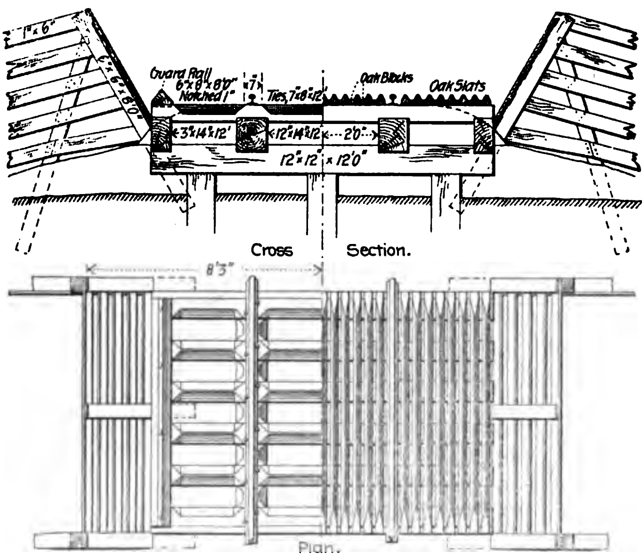


Fig. 86.—Pit Cattleguard.

clear of the track, and in fact a pit designed for such a purpose would necessarily be almost entirely open, and therefore dangerous in other ways. In case of a derailed wheel or truck reaching the guard the beveled ties would afford little greater security than the open pit. Another plan, also shown in Fig. 86, has ordinary ties laid on the stringers, and a series of longitudinal beveled wooden slats nailed upon them, parallel with the rails. The pit guard, however, has many disadvantages and objections, and it is as dangerous a structure as the open culvert, which latter structure railways are rapidly eliminating. In case of a derailed wheel or truck the pit is almost certain to cause a wreck, while cattle are very liable to fall into a pit whether entirely open or crossed by beveled ties. The pit also makes a bad riding place in the track, by breaking up the continuity of the road-

bed, and in case of track heaving on either side the blocking or shimming of the rail on the stringers is not easily done so as to make a good piece of work. As the pit is below subgrade, the frost is likely also to heave the side walls. The timbers are also likely to catch fire, to rot. or to settle; and the pit forms a receptacle for dirt, refuse and moisture.

Surface Cattleguards.—These are rapidly supplanting the old pit guard, since they are free from danger to trains, and (if properly constructed) are fully as efficient in turning cattle. The simplest form consists of wooden slats 5 to 8 ft. long, and of triangular section, made from 3½ or 4-in. pine sticks cut diagonally, nailed to the ties, but these are generally seen only on branches and small country lines, and are, as a rule, in poor condition, with slats split, broken off or ripped up. A better plan is to have slats and spacing blocks bolted together in sections. One or two of such sections are placed between the rails, and two are placed outside the rails. Other sections are placed in the space between the tracks on a double track line, being nailed to three or four ties placed between the tracks. The construction is similar to that covering the right hand side of the pit cattleguard, Fig. 86, the slats being about 10 ft. long, 4 ins. deep, ½-in. wide on top, and 2 ins. on the bottom, the lower 2 ins. of the sides being vertical, so as to fit the spacing blocks, 2 x 2 ins., and 8 ins. long, placed between the slats at the ends and middle. The parts are held together by three ⅝-in. rods passing through the slats and spacing blocks. In some cases a strip of barbed or twisted wire is nailed along the tops of the slats, but these are liable to get loose and make a very poor looking guard.

Among the various designs for surface guards are some in which the animals are compelled to step on planks between the ties, which planks are loose, and are connected to a transverse rod carrying several prongs 18 to 24 ins. long, forming a fence which rises in front of the animal, but lies normally flat on the ties. A simpler plan consists of four or five rows of 10-in. drain tiles placed on end between the ties, the latter being capped by timbers of triangular section. The tiles are about 18 ins. long, placed on a bed of gravel 3 or 4 ins. thick to provide drainage, and have their tops level with or a little above the rail head. Snow can be removed with a scoop, and renewals are easily effected. Vitrified blocks forming triangular ridges parallel with the rails have been tried, but have the objection of covering the ties and tending to cause decay, like some of the metal surface guards.

Metal surface guards are now very generally adopted as they are efficient, economical, permanent, and do not interfere with the track work. The majority of these consist of a series of iron slats or rods parallel with the rails, and arranged to form but an insecure footing. One of these (of the Bush type), used on the Pennsylvania Lines West of Pittsburg, is shown in Fig. 87. The slats are supported in triangular iron cross-pieces, and are set alternately high and low. In some cases flat bars set on edge are used, having wavy or saw-tooth top edges, and sometimes barbs on the sides, so as to cause pain to any animal making a determined effort to cross. Flat plates sometimes have teeth punched up out of the metal for the same purpose. While the teeth and barbs may add to the effectiveness of the guard in turning hogs and small stock, they are open to the objection of possibly causing injury to stock, for which the railway company may be held liable. Such

cattleguards have also been the cause of serious injury to flagmen sent back from trains, and to other persons walking on the track. Metal guards which have a flat bottom plate covering the ties and ballast have disadvantages over the slat forms in interfering with tamping and track work, and being

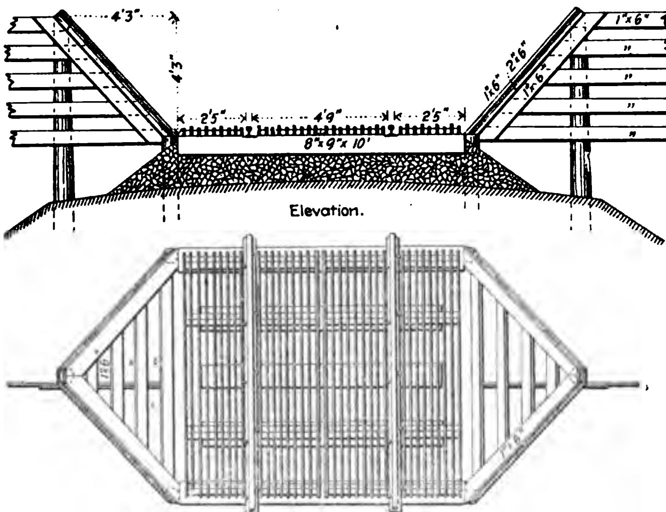


Fig. 87.—Metal Surface Cattleguard; Pennsylvania Lines.

liable to cause rotting of the ties by holding water between the plate and tie, while the heat of the plate in summer also aids in this effect.

While the old style of pit cattleguard is objectionable in many ways, and is an element of danger to traffic, it has proved more effectual in turning stock than some of the surface cattleguards designed to supersede it. Its specially deterrent feature is the depth of the pit, the sight of which discourages animals which try to cross. In view of these conditions the Wal-

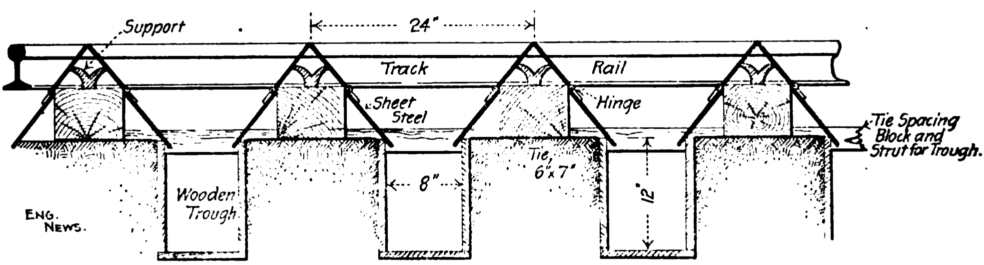


Fig. 88.—Wallace Cattleguard. (The troughs should be V-shaped, affording no footing.)

lace combination cattleguard, Fig. 88, has been introduced on the Arkansas Midland Ry. It has sufficient depth below the rail, gives no foothold for animals, and is yet a part of the track and can be readily inspected and repaired. The ties are spaced 24 ins. c. to c., and the earth is shoveled out

between and below them to form trenches, in which are set wooden or pressed steel troughs. The cut shows flat-bottomed troughs, but they are preferably of V-shape, so as to afford no footing to the most persistent animal. Under the rails are put blocks to prevent the ties from shifting, and to brace the tops of the trough. Over each tie is set an inverted trough of V-section, made in three parts to cover the middle and ends of the ties. The sides are in two parts hinged together, so that the lower part can be

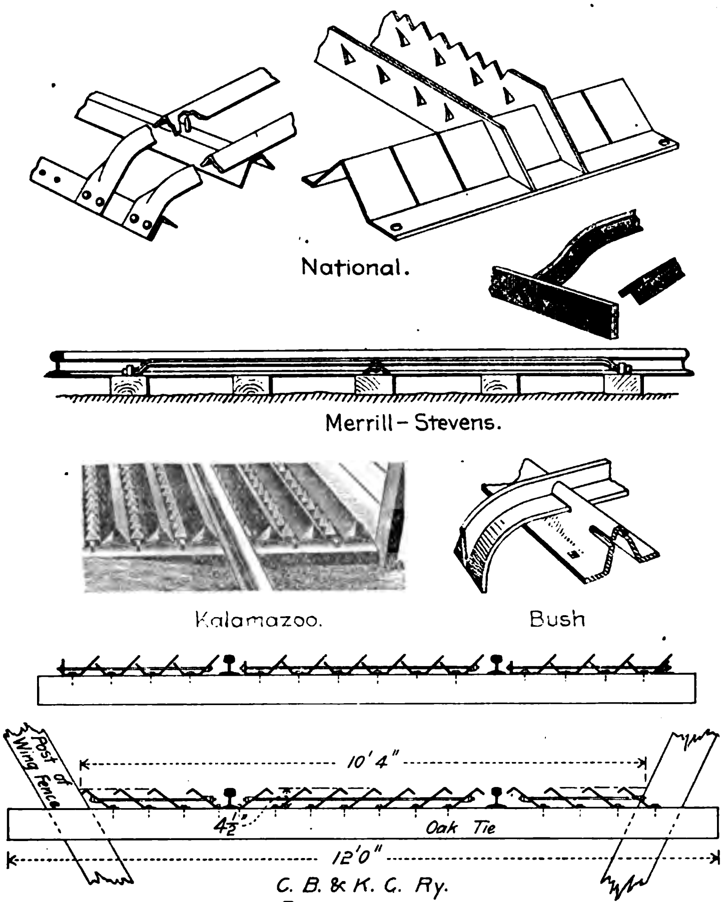


Fig. 89.—Metal Cattleguards.

thrown up to allow of tamping the ties. As there is plenty of air space it is not expected that the covering will affect the life of the ies.

Some metal surface guards are shown in Fig. 89. The Kalamazoo guard has triangular ridges, and triangular teeth punched up out of the flat strips of plate between the ridges, so that an animal's hoof will slip down upon the teeth; the ridges are higher than the teeth, so that a person falling on

the guard would not be likely to be badly hurt. This guard, 9 ft. long, weighs about 375 lbs. The National guard has slats of T or Λ section attached to cross pieces, alternate slats being 1⅛ ins. above the others. A guard 9 ft. long and 10 ft. wide across the track, weighs about 400 lbs. Another form of the National guard has flat plates, 2⅛ and 3½ ins. high, 2¾ ins. apart, set on edge in the transverse pieces; this weighs 560 lbs., or 140 lbs. for each of the four sections. The tops of the plates may have saw teeth pointing towards the highway, and where small stock are to be dealt with the plates may have barbs punched out of the sides and pointing diagonally upward; this latter plan has been specially designed for the southern "razor-back" hog, who usually surmounts any cattleguard. The Merrill-Stevens guard has slats of T-iron, about 1¼ x 1¼ ins., parallel with the rails, set diagonally in the end cross pieces, and made level with the rail head; the space beneath the guard and the insecure footing of the slanting bars tend to check cattle from attempting to cross. The Standard guard has slats of flat or Z-shaped plates, parallel with the rail and set to incline towards the rails, the lower edge of each plate being bent to form a supporting ridge for the adjacent slat. The Bush guard has slats of inverted T-irons, 2 ins. apart, carried in slotted cross-pieces of pressed steel, the bars being at different heights; this guard is made in four interchangeable sections and weighs about 450 lbs. The metal cattleguards are more expensive than the others in first cost, but they are more durable, require little attention, and are independent of the track construction.

Wing Fences.—To shut off the right of way between the track and the boundary fence, a board or wire wing fence is built opposite the middle or end of the cattleguard, and should have the end post inclined away from the track, so as not to be struck by persons on car steps or freight car ladders. The clear width between wing fence posts at rail level should be 10 ft. to 12 ft. on single track. Sometimes the wing fences alone are used, but the more general practice is to put a rectangular or triangular panel of apron fence on each end post, parallel with the track, as shown in Figs. 86 and 87. The ditch may be closed against small animals by stakes driven into the ground and nailed to the bottom of the wing fence. The wing and apron fences should be kept in good repair and well whitewashed, as cattle object to passing a whitewashed fence more than an ordinary fence.

CHAPTER 9.—BRIDGE FLOORS AND GRADE CROSSINGS.

While solid floors for steel bridges are coming into more general use, the most common form is still the open floor, consisting of sawed ties laid upon the track stringers of through bridges or the top chords of deck bridges, and secured by hook bolts taking hold of the flanges of stringers or chords. In rare cases, the rails are laid on longitudinal timbers, as on the Long Bridge of the Pennsylvania Ry., at Washington, and on the old Victoria Bridge of the Grand Trunk Ry., at Montreal. In designing the floor system of a bridge or trestle, the emergency of derailed trains must be provided for. This need involve but little additional expense, but may save many lives and many thousands of dollars in case of a derailment. The flimsy construction of the floor on the iron deck truss bridge of the Grand Trunk

Ry., at St. George, Ont., caused the wreck of a derailed train in 1889, with a loss of about 13 lives and $200,000, while it was estimated that for $520 a floor could have been built which would have carried the train This floor had ties at least 8 ins. apart in the clear, with guard rails on the ends of the ties only, so that the wheels easily "bunched" the ties, leaving wide gaps into which the wheels dropped. Bridge ties should be not more than 4 ins. apart in the clear, and kept from bunching by having the guard timbers boxed out over each tie, or by having spacing blocks between the ties. Every tie or alternate tie should be secured to the stringers by hook bolts on metal structures, or by drift bolts or screw bolts on timber structures. Sawed ties of oak or yellow pine are commonly used, the latter being less liable to warp. For single track, the length may be 8½ ft. to 16 ft. Sometimes the standard length is 10 ft., and every fourth tie is 14 ft. long, carrying two lines of planks for a footwalk. On double track, timbers 24 ft. long may be used, carrying both tracks. Bridge ties are usually 8 × 8 ins. to 10 × 10 ins. or 10 × 12 ins. section, and sometimes 8 × 16 ins. It has been proposed to build deck plate girders without cover plates on top, riveting them to the sides of the chord, so that ties will not have to be notched or bored to fit the rivet heads.

Solid floors for steel bridges have advantages in safety, permanence and smooth riding. The first cost is, of course, greater, but there is a decided saving in maintenance work, while with a ballasted floor the track maintenance can be regularly attended to by the permanent section gangs instead of by the bridge gangs. Ballasted floors are generally preferable to bare floors. They enable the standard track construction to be carried across the bridge, while the extra dead load of the heavier floor and the ballast not only requires a heavier construction of bridge, but the ballasted floor absorbs much of the vibration which causes objectionable noise and is detrimental to metal bridges. As a rule, the floors are built up of transverse troughs of rectangular or trapezoidal section, but are sometimes formed of flat deck plates over the floor beams. Some roads consider that ballast tends to corrosion of the floor, and prefer to use deep ties resting in the troughs, but experience has shown that the objection is of little importance. On the track elevation work in Chicago, with some 474 plate girder through bridges, most of the roads have unballasted solid floors, with the rails bolted directly to the deck plates or resting on strips of wood. The noise in the street and in the cars is very pronounced. The Pennsylvania Lines, however, have used a trough floor and ballast 6½ ins. deep above the troughs, with the result that the passage of trains over these bridges is hardly noticeable in the street or in the cars. On the solid floor of the New York Central Ry. viaduct in New York, the 100-lb. rails were at first bolted directly to the transverse troughs of the floor system, steel tie-plates being used, and as the rails form a circuit for the block signal system they were insulated from the floor by means of fiber packing. The noise of traffic on this structure, however, was so great that to stop complaints the troughs were filled with broken stone and the rails laid on creosoted wooden ties embedded in the ballast, tie plates being used on every tie. By this means the noise has been almost entirely stopped. The thunderous reverberating sound caused by trains running on plate girder viaducts, with or without solid floors, suggests the desirability of using a cushion bed of ballast to

absorb the vibrations. This is specially important on city viaducts, as noted above in regard to New York and Chicago.

For plate girder deck bridges, ballasted floors of transverse troughs or old rails have been used to some extent. The Chicago & Northwestern Ry. has some double track bridges of this type, with floors of transverse troughs 28 ft. long, overhanging the outer girders about 4 ft. Along each side is a light plate girder 21 ins. deep, with gusset plates riveted to the floor, and gravel ballast is filled in to a depth of about 25 ins. above the troughs, the ties being embedded in the ballast. For through plate girders, 13 ft. c. to c., transverse 15-in. I-beams 3 ft. 7½ ins. apart, carry two lines of 15-in. longitudinal channels riveted to their webs, and in each floor panel is a ⅜-in. buckle plate, 3⅓ × 11 ft., with a drainage hole. The buckle plates and I-beams are covered with asphalt ½-in. thick, and a 1-in. layer of asphalt and sand is placed on the floor. Gravel ballast is filled in, the drainage holes being protected by stones, and the ties are embedded in the ballast. The floor is quite thin, only 16 ins. from bottom of floor beam to base of rail. Fig. 90 shows a floor of old rails on a deck bridge of the Chesapeake & Ohio Ry. The rails are 70-lbs. per yd., 4 ins. high, spaced 6 ins. c. to c., so as to fit between the rivet heads. The rails are 10 ft. 5 ins. long for single track and 23 ft. 5 ins. for double track. An angle iron ½ × 6 × 6 ins. on each side of the floor, is secured to the extra wide bottom plate of the chord by ⅞-in. bolts, 12 ins. apart. To the vertical flange of this angle iron is riveted a

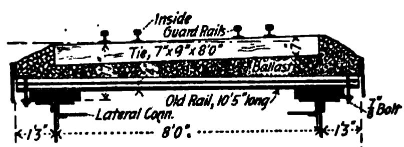


Fig. 90.—Bridge Floor of Old Rails; Chesapeake & Ohio Ry.

plate ⅜ × 12 ins. to retain the ballast, which is 4 ins. deep under the ties. The floor is well coated with tar, and the spaces between the rails allow for drainage. An angle iron retains the ballast at each end of the bridge, and a plate covers the space between the bridge and the back wall of the abutment. A greater depth of ballast and greater width of floor would be preferable. Floors of longitudinal troughs, carried on the floor beams, have been used in some cases. In Europe, the floor is sometimes made to form a deep trough for each rail, in which derailed wheels would run, but this plan is rarely used here. No general plan can be laid down for solid floors, but various designs may be made to suit different classes of bridge. The design should be made with special regard to strength and safety, and with reasonable regard to weight and economy also.

Open culverts and small trestles may often be advantageously replaced by solid banks, having masonry arches or iron pipes for the waterway. Where the depth is insufficient for an embankment, concrete or masonry walls may be built to carry a solid floor of short plate girders (which may be built from scrap at the shops), old rails or steel troughs. The Michigan Central Ry. uses concrete side walls, spanned by plate girders carrying I-beams 12 ins. c. to c., with ⅜-in. deck plates. The ballast is put over this to a depth

of at least 12 ins. under the ties. The New York Central Ry. uses a single row of old 65-lb. rails (laid closely, side by side) for a clear span of 8 ft., reinforcing this for a span of 10 ft. by four inverted rails under each track rail. These floors are covered with broken stone ballast, about 15 ins. deep, under the ties. For spans of 15 to 30 ft., longitudinal trough floors are used, the troughs being built up of rectangular section, 12 ins. wide and 16 ins. deep. Rolled troughs may also be used for short spans. On some roads the rail floors are covered with concrete about 12 ins. thick at the middle and 4 ins. at the sides, the ballast being laid upon this. The rails should be held together by tie rods at the ends. For crossing irrigation ditches, the Southern Pacific Ry. uses two 12-in. channel irons under each rail, the channels being placed back to back, with riveted channel iron bearing pieces or saddles between. The saddles carry creosoted blocks, 4 × 12 ins., 12 ins. long, and the rails are bolted through these to the saddles. The channels weigh 30 and 50 lbs. per ft. for spans of 12 and 15 ft., and their ends rest on shoes on 12 × 12-in. cap sills. It would be better to use wooden stringers instead of wooden blocks, so as to give a continuous bearing for derailed wheels. For crossing gutters which have to carry surface water, the railway sometimes uses two pieces of old rail bolted together at intervals of 18 ins., the track rail resting on the spacing sleeves on the bolts, the length of the sleeves being equal to the width of the rail base.

On iron structures, corrosion is often caused by brine dripping from refrigerator cars. To prevent this, planks 1 × 6 ins. may be nailed under the ties, a strip 1 × 2 ins., or the width of the tie spacing, being nailed to the top of the plank. The bottom of the troughs thus formed may be coated with tar, and a trough laid along one side of the ties to catch the water, brine, etc., which is carried off by drain pipes. On solid floors, experiments have been made with asphalt and paint, and with a tar and gravel composition, the plates being first calked with hemp. This prevents the leakage of water through the floor, and, if put on thick, has some effect in deadening the sound of trains.

Ballasted floors for trestles built of creosoted timber have been in use on the Louisville & Nashville Ry. for over 20 years, and those 20 years old are still in good condition. The trestles have bents 13 ft. c. to c., with 12-ft caps, 12 × 14 ins. Upon the caps are six lines of stringers, 17 ins. apart in the clear, each composed of two planks 3 × 16 ins., 28 ft. long, breaking joints and spiked together. They are easily accessible for repairs. Between the stringers, over the caps, are double bridging pieces, 2 × 4 ins. Upon the stringers is a floor of transverse planks, 3 × 8 ins., 12 ft. long, bolted through the stringers and caps, and having curb timbers 6 × 8 ins. The ballast is rather thin, being only 4 ins. deep under the ties, and is filled in level with the tops of the ties. Creosoted piles are extensively used in salt water, but on the northern divisions cedar piles are generally used. Solid floor trestles on the Illinois Central Ry. have 14 longitudinal cypress timbers 10 × 12 ins., with similar timbers on each side for copings. These copings are fastened at the caps and midway between them, by ¾-in. bolts, 42½ ins. long. On each side of the caps, planks 2 × 6 ins., 11 ft. 8 ins. long, are spiked to the underside of the floor timbers by boat spikes ⅜ × 6 ins. These prevent any creeping of the floor upon the caps, which are very wide. The timbers are of black and red cypress, not creosoted, and last about 12 years in the low,

swampy country of the South. The first cost is 10 to 20% in excess of that of open-floor trestles, but they are very durable, and are safer, while all track work is done by the regular section gangs instead of by special bridge gangs. Ballasted floor culverts, Fig. 91, are used on the Southern Pacific Ry. Four piles at each end carry caps 12 x 12 ins., 12 ft. long where 8-ft. ties are used, and 13 ft. for 9-ft. ties. These support a close floor of longitudinal timbers, with coping timbers 4 x 6 ins. The floor timbers vary in depth from 6 ins. for 4-ft. spans, to 8 ins. for 10-ft. and 12 ins. for 14-ft. spans. There is a good supply of ballast, 9 ins. thick under the ties, and the face of the bank at each end is held up by planks behind the piles. For culverts having two bents, the caps are 13 ft. long, with 13 floor timbers. Guard timbers should be used, as on standard trestle floors. These solid floors have the following advantages: (1) Safety from fire; (2) Low cost of maintenance, as repairs are small, and the lining and surfacing can be done by the section gangs instead of by the bridge gangs; (3) They give an easy riding track, and (if provided with proper guard rails) there is less liability of damage in case of derailment.

A plan adopted on the Richmond, Fredericksburg & Potomac Ry. to protect the floors of timber structures from fire, is to fasten boards, 2 or 3 ins.

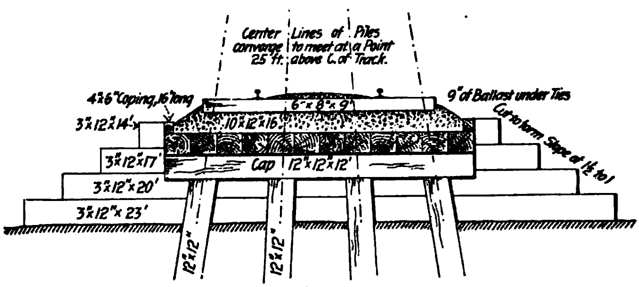


Fig. 91.—Ballasted Culvert; Southern Pacific Ry.

thick and 6 ins. wide, under the ties and along their ends, forming troughs which are filled with gravel. The durability of the stringers is not affected, and the arrangement is considered preferable to the open floor. On some of the long, high trestles of the Canadian Pacific Ry., which are not likely to be replaced by permanent structures for some years, and which are so located as to make reconstruction difficult in case they should be destroyed by fire, the floor is protected from sparks and hot cinders by laying planks across the ties and filling in gravel or cinders to a depth of 2½ or 3 ins. On long trestles or deck bridges there should be a plank foot walk on one side or between the tracks, or else refuge places should be provided at intervals. The latter may be conveniently located where the water barrels are placed on trestles.

Bridge Guard Rails.

A bridge floor is a dangerous place for a derailed car or train; and in addition to a substantial floor construction, special means should be taken to prevent derailed cars from striking the bridge or falling over the side. As a general thing all bridge floors are provided with wooden guard rails,

placed outside the track rails and bolted to the ties. These guard timbers are usually 6 × 8 ins. (which is too small) to 10 × 8 ins. (laid flat) or 10 × 10 ins. They should be boxed out ¾-in. to 1¼ ins. for the ties and bolted to every tie, or every second or third tie, by a ¾-in bolt, the head resting on an ordinary washer about ¾ × 3½ ins. or in a cup washer let into the timber. On trestles with jack stringers the bolts may go through the stringers. The joints are usually scarfed vertically, with a bolt through the scarf. The timbers are usually set 10 to 18 ins. from the gage side of the rail head, or 7 to 9 ft. apart. The sooner a derailed wheel is met and guided, the less is the liability of its causing trouble, and with guard timbers more than 8 ft. apart the wheels have a chance to turn or slew to such an angle as to be more likely to break or move the guard, or to climb over it. The purpose of the wider spacing is claimed to be to provide for wheels very far off the track, but these should be provided for by flaring the timbers out on the approach for a distance of 30 to 60 ft., so as to catch any wandering wheels and guide them into position for crossing the bridge in safety. The guard timbers are more thoroughly effective if faced with angle irons on the top corners. In some cases the guards serve merely to keep the ties from bunching, being so far apart that a derailed car would strike the bridge truss before the wheels encountered the guard. This is not good practice, but on wide bridges with long ties, extra timbers are sometimes placed near the ends of the ties.

Iron guard rails placed between the track rails are very commonly used, either with or without the outside guard timbers, but it is better to use both. On some roads, however, the inside guard rail is considered rather an element of danger than of safety, though the general opinion is quite the reverse. They are of old or new rails, well spiked and spliced, spaced 5 to 12 ins. clear from the gage side of the track rail, the spacing being sufficient to allow derailed wheels to run between the guard and track rails. They should be extended about 150 ft. on the approach, being gradually brought together and bolted to an old frog point or special point, beveled so as not to catch loose chains or brakebeams. At the leaving end of the bridge on double track, the rails need extend but a few feet beyond the structure. Heavy angle irons, with the horizontal flange set either to or away from the track rails, are sometimes used for guards. In some cases, also, there are inside guard timbers, with an angle iron on the top corner, or laid on the ties and bolted through the guard timber so as to form a path for derailed wheels. Such wheels are less likely to burst or mount inside guard rails, as the back of the wheel bears against them while the sharp flange would strike an outside guard. It has been proposed to lay each rail in an iron trough (see Bridge Floors), or in a 15-in. channel iron, leaving about 6 ins. clear between each side of the rail head and the flanges of the channel. It is questionable, however, whether these flanges would serve the intended purpose effectively.

Rerailing devices are not so generally used as they should be, in view of their importance as safety devices. They are intended, as their name implies, to replace derailed wheels upon the rails. One of the best of these is the well-known Latimer rerailing guard, a modified form of which is shown in Fig. 92. The wheels are carried up the incline, and guided laterally until their flanges drop into position on the inside of the rail head.

In the modified Childs-Latimer rerailing guard, inclined blocks are fitted inside and outside the track rails at the abutment, where the guard rails begin to converge. It is sometimes considered best to place such devices 50 to 150 ft. from the bridge, so that if the wheels are too far out to be saved the car will be wrecked on the approach and not on the structure. The possibility of a car being so far off the track that its wheels are beyond

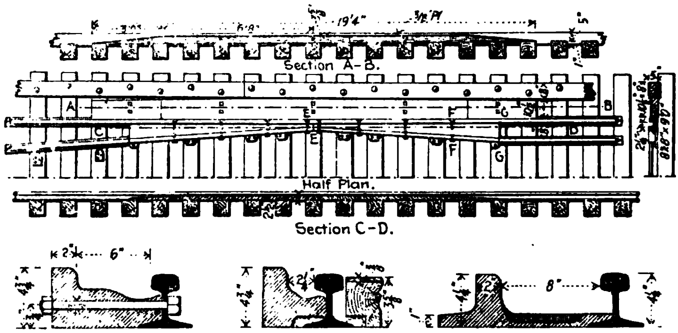


Fig. 92.—Rerailing Device at Bridges.

the center line, and will take the wrong side of the guard rail point, may be provided for by placing special guard timbers or guard rails just ahead of this point. These rails would be 30 ft. long, 8 or 10 ins. from the track rails opposite the guard rail point, and flaring out to 4 ft. 8½ ins. from them. A piece of rail 15 ft. long should extend from the inner ends of these guards towards the bridge (being parallel with the track rails), and a rerailing device may be set between them and the track rails. Flaring guard timbers at bridge approaches or entrances should be laid on long ties firmly bedded and tamped in good ballast for their entire length. In some cases, bumper posts are placed on the approach in line with the bridge trusses, so that a derailed car far enough off the track to strike the truss would have its trucks stripped from under it before reaching the structure. These bumpers may be formed of three piles in a cluster or a timber 16 × 16 ins., 10 or 12 ft. long, with 4 ft. above ground.

The standard bridge floor of the New York, New Haven & Hartford Ry., Fig. 93, has ties 11 ft. long for single track and 24 ft. for double track, all

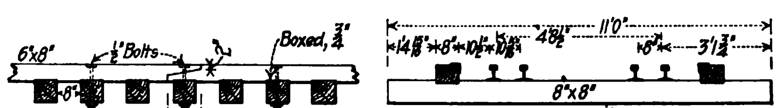


Fig. 93.—Bridge Guard Rails; New York, New Haven & Hartford Ry.

8 × 8 ins., 8 ins. apart (which is too far). The outside guard timbers are 6 × 8 ins., laid flat, boxed out ¾-in. for the ties, and faced on the upper corner with an angle iron ¼ × 2½ × 3 ins., secured by countersunk 5-16-in. screws, 3 ins. long, 24 ins. apart on the top and side, staggered. The timbers are 10¼ ins. from the outside of the track rails, and flare out till they are

10 ft. apart, 83 ft. from the edge of the bridge, the end ties being 12 ft. long. They end 8 ft. beyond the point of the inside guard rails, being there 9 ft. apart in the clear opposite the point. The inside guard rails are 8 ins. clear from the track rails to a point 15 ft. beyond the abutment, whence they are inclined on a flat curve for 60 ft., until they meet at a point. At the leaving end, on double track, the guard timbers and rails end 5 ft. beyond the end of the bridge. The Erie Ry. uses inside guards 7 ins. clear from the track rails and outside guard timbers 16¾ ins. from the gage side of the track rail. On the Northern Pacific Ry., the ties are 10 × 9 ins., 14 ins. c. to c., and are 12 ft. long. The inside guard rails are 8 ins. and the outside timbers 26 ins. clear from the track rails. The timbers are 6 × 8 ins., laid flat, and boxed out 1½ ins. The Kansas City Southern Ry. has yellow pine ties 8 ins. wide and 10 ins. high, boxed out ½-in. over the stringers, and spaced 5 ins. apart. The standard length is 10 ft., but every fourth tie is 14 ft. long, and carries two lines of plank as a walk for trackmen, etc. The 60-lb. track rails have 60-lb. inside guard rails 5 ins. from them. The outside guard timbers are 8 × 10 ins., laid flat, boxed out 2 ins. (which is an unusual depth, intended to provide ample security against "bunching" of the ties), and bolted to every tie, the ¾-in. bolts being staggered in two rows. The timbers are 8 ft. c. to c. The Michigan Central Ry. uses the Jordan guard, consisting of three lines of rails between and parallel with the track rails.

All openings, culverts, waterways, small trestles, etc., are a source of danger, and should have guard timbers at least, with the timbers flaring out on long ties beyond the abutmments. Small structures of this kind, however, too often have short ties, with mere sticks of guard rails on the ends, while the ballast slope is continued right up to the floor, so that a derailed wheel would strike the end of the structure instead of running across it. Trestles with long ties may have jack stringers under the outer guard rails to prevent the ties from being tilted up by derailed trucks. Trestles and bridges for electric railways are very often deficient in guards, although with light cars run at high speed there is often great danger of derailment. In fact many serious accidents have happened in this way.

Elevated Railways.

The floor and track construction of elevated railways usually resembles that of bridges, except that there are generally inside and outside guard timbers secured to the ties by wooden pins or iron screw bolts, the nuts of the latter being usually in cup-shaped washers let into the tops of the timber. These timbers are frequently faced with angle iron on the top inner corners, and are heavily reinforced by additional timbers on curves, while the inside timbers are replaced by iron guard rails on the low side of sharp curves. The New York elevated railways have 90-lb. rails, with suspended or bridge joints, and have 20 ties per rail, with tie-plates on each tie. The track of the South Side Elevated Ry., Chicago, is shown in Fig. 94, but the wide spacing of the ties is an objectionable feature. The 90-lb. rails are secured by spikes 9-16 × 3½ ins. to hardwood ties 6 × 8 ins., 8 ft. long, the joint ties being spaced 13 ins. c. to c. and the intermediate ties 20⅛ ins. c. to c. The ties are fastened to the top chords of the girders by ¾-in. hook

bolts. The four guard timbers are 6 ins. wide and 8 ins. high, the inner ones 4 ins. from the rail and bolted to alternate ties, while the outer ones are 11 ins. from the gage side of the rail and are bolted to every tie. Extending between the tracks, or in some places on the outer side, are timbers 6 × 6 ins., carrying four lines of plank 2 × 6 ins., forming a walk for the trackmen and employees. The outer walks are usually protected by gas pipe hand rails. The line is operated by electricity, the third rails (not shown) being carried on insulators just outside of and a little above the outer guard timbers. In some cases ties have been dispensed with, and each line of rails rests on wooden blocks or saddles riveted between a pair of channels placed close together and acting as guard rails. This system was originally used on the Hoboken line, but when the company began running its electric surface cars over the line, cross ties were substituted, resting

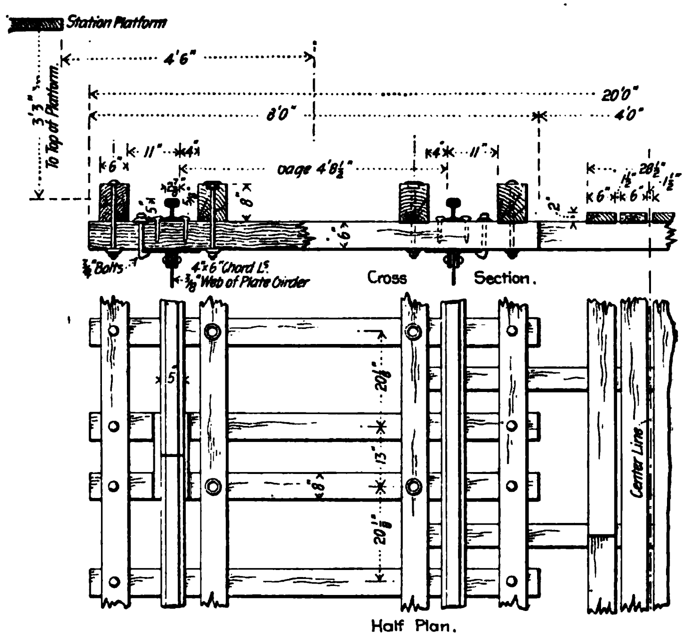


Fig. 94.—Track and Floor System; South Side Elevated Electric Ry. (Chicago).

on the channel stringers. This was partly on account of the attachments allowing too much lateral play of the rails to suit the narrow tired wheels, and partly because the gear cases came too near the stringers. The Kansas City line has 48-ft. pin-connected trusses with top chords of two 10-in. channels, 8 ins. apart, having bent steel plates riveted between their webs at intervals of 16 ins. The rails were originally laid directly on these plates, but this arrangement caused considerable noise and the rails are now spiked to ties laid across the chords in the usual way. It has been proposed to lay longitudinal timbers in a similar way to the above, giving greater security than the blocks, and less obstruction to light than the

ties. The latter point is important for lines built in city streets. Felt packing under the timbers would reduce the noise.

Road and Street Crossings.

The avoidance of grade crossings has rarely been a consideration in railway location in this country, and it is worthy of note that in the St. Louis extension of the St. Louis, Keokuk & Northwestern Ry., built in 1894, the grade line was laid out as to avoid crossing at grade wherever possible, some of the roads having their grades slightly changed on condition that the railway company would macadamize the roads. Inexpensive timber or plate girder bridges were used. In too many cases, railways still run through towns and cities on the street grade, generally having their own right of way and merely crossing the streets, but sometimes running along the middle or side of a street, and in such cases it is very difficult to keep the track in good condition. In many cities steps have been taken to eliminate the grade crossings, the railway being either depressed and laid in an open cut with retaining walls, and crossed by bridges, or raised on a viaduct or bank and crossing the streets by bridges. Street grades are very frequently changed at the same time so as not to require the tracks to be raised higher than necessary. Such work is often very difficult and almost invariably very expensive, involving a large amount of railway and municipal work, and the execution of the work during traffic, which is an unfavorable condition for economy. The railway, however, is free from the expenses incident to gates, watchmen, accidents, etc., and from the delays caused by crossings, so that it can operate its traffic to better advantage. In Chicago the comprehensive system of elevated tracks includes about 60 miles of line, with 280 miles of main track and 575 miles of track of all kinds, eliminating some 400 grade crossings. The cost is about $15,000,000, all paid by the railways. This work was described in Engineering News, Jan. 11 and Feb. 22, 1900.

Where the tracks run along or across city streets, an iron guard rail is generally placed inside the track rail, and the paving filled in over the ties, leaving only a flangeway, which should have a filling piece up to the level of the underside of the rail heads. In some cases a line of planking is laid along the outside of the rail head. A substantial form of construction through paved streets has been tried by the New York Central Ry., but is expensive and not entirely satisfactory. With this system, the ties are placed 4 ins. deeper than usual, laid upon 6 ins. of gravel ballast, with 6 ins. of concrete between the ties and extending to the sides of the street. Upon each tie are spiked two iron chairs 4 ins. high, with a base of 10¼ × 4¼ ins., and weighing 21 to 28 lbs. each, for intermediate and joint chairs. Upon these are laid the track rails, secured by steel spring clamps of approximately semicircular form, which are driven on parallel with the rail, gripping the rail flange and top of chair. The chair brings the top of the rail to the level of the paving blocks. To the inside of the web of each rail is bolted a continuous angle bar of special section with a broad flange at the top, the built-up section resembling a side-bearing street-rail, the depth of flange being the full depth of the rail head, or 1 9-32 ins. for an 80-lb. rail. The bolts are at intervals of 4 ft. 4½ ins., and at the rail joints

only an outer six-bolt splice bar is required, the clamps on the three joint chairs gripping the flange of this bar. The track and special rails break joint about 18 ins. Over the concrete and ties is a 2-in. layer of fine sand, upon which are set the paving blocks, the outside blocks being level with the top of the rail, and the inside blocks level with the top of the angle bar. The cost is about $13,500 per mile of single track, laid and ballasted, but exclusive of concrete and paving, which is the city's work.

Country road crossings are usually either planked all the way across or have planks against the rails, with gravel or cinder filling between. The planks are 3 × 8, 3 × 12 or 4 × 12 ins., 8 to 12 ft. long for farm crossings and side roads, or 30 ft. for main roads. Five 10-in. or four 12-in. planks will fill in neatly between the rails, while a similar plank will be laid outside of each rail. If the rails are high, the planks rest on strips nailed to the ties, so as to bring the planks flush with the top of the rails or ½-in. below. The ends of the planks are adzed to an incline of 6 to 12 ins. at the ends, so as not to catch loose hanging rods, chains or breakbeams. Pine planks are more suitable than spruce or oak, the former being too soft and the latter having a tendency to warp. They should be spiked by ⅝-in. boat spikes, 7 or 8 ins. long, track spikes being too short and more expensive. The outer planks are laid close against the rail heads, but the inner ones must leave flangeways about 2½ ins. wide. These planks may be set that distance from the rail, or their edges may be rabbeted to fit under the rail heads, leaving flangeways 2½ ins. wide and the full depth of the rail head. A shallow flangeway has the objection of being more easily obstructed by loose stones, etc., but if the space is left open for the full depth of the rail, horses are liable to get the calks of their shoes caught under the rail head. It is generally best, therefore, to put in a filler against the web. If the planks are laid only against the rails, cross planks may be laid between their ends, forming a shallow box to be filled in with broken stone or gravel for roads, or gravel or cinders for private and farm crossings. Where track is liable to heave, the planks may be removed from unimportant crossings in the winter, so as not to be struck by engine pilots or snow plows. At narrow crossings the planks should, if possible, be placed so as not to cover any rail joints. It is difficult to properly inspect and repair such joints, and in some cases 60-ft. rails are used to bring the joints beyond the crossings.

A steel rail is frequently placed as an inside guard rail to form the flangeway and protect the edges of the planking or the gravel filling. If placed upright or laid on its side with its base toward the track rail, a wooden filler strip should be placed against the web of the track rail, as already noted. In the latter arrangement a plank must be cut to shape to rest upon the guard rail, the plank being secured by long spikes driven through holes in the rail web. Another plan is to lay the rail on its side, with its head resting against the web of the track rail, thus forming a shallow flangeway with filler. The ends of the guard rails should be flared out from 6 to 12 ins. at the ends, giving a clearance of at least 4 ins., this space being filled with some form of footguard. For busy crossings on the Toledo, Peoria & Western Ry., guard rails are used in the position last described, with six planks 3 × 12 ins. (four between the rails) laid on 1-in. strips. For minor crossings, planks are laid outside the

rails and old steel rails are laid inside, standing upright and having a filling of broken stone between them. The flangeway is 2½ ins. wide. The planks are 20 to 30 ft. long, according to the width of the road. Two plans of road crossings are shown in Fig 95.

The approaches to the crossings should be properly built and graded, and may be carried across the roadway ditches by planks spiked to timbers or old ties, resting on the bank and the roadbed, but these timbers are liable to rot and easily become loose, making an unsightly crossing. It is generally better to carry the ditch through by a box drain about 8 × 10 ins., or an iron pipe 8 to 12 ins. diameter, and then to fill in the earth to make a properly graded approach. Clay pipe is likely to be broken or displaced unless the earth cover over it is pretty thick, while a wooden box drain is likely to break or decay and allow the earth to fall in and block the drain. The ends of the pipe or drain may be laid in small dry walls and be covered by screens. These pipes should be of ample capacity, and should be cleaned out occasionally. Crossings should always be kept in good repair, not only on account of the safety of railway and highway traffic, but also because defective and unsightly crossings are a frequent cause of public complaint, leading to an ill-feeling against the railway.

Road Crossing Signals and Gates.—Country road crossings are generally protected only by warning signs and cattleguards, though flagmen are

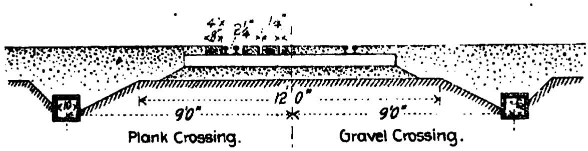


Fig. 95.—Road Crossings.

employed in some cases, and gates and automatic bell or gong signals are also sometimes used. For suburban crossings of busy lines, signs and gates are very generally used (or flagmen instead of gatemen), and are often supplemented by automatic gong signals, having either a large gong to warn persons approaching the railway, or a small gong to warn the watchman to flag the highway traffic or to close the gates. These audible signals are of two classes; in one the train puts in motion a force which will ring the gong for a certain time, and in the other the train closes an electric circuit, so that the gong continues to ring until the train has passed the crossing. Many of these appliances have proved uncertain in action, and this unreliability is specially dangerous at crossings where this is the only warning, as persons who have once found the gong inoperative are likely to disregard it in the future. Some of these signals, however, are reliable within all reasonable requirements, and an automatic audible signal is valuable as an auxiliary to the gateman. In this connection it is pertinent to call attention to the folly of paying poor wages and employing cheap and incompetent men as flagmen or gatemen at crossings. Such men will not and do not attend faithfully to their duties, and many accidents have resulted from the carelessness of such watchmen.

In many of the automatic signaling devices the apparatus is set in operation by some sort of track instrument operated by the wheels, but

others are operated from an electric circuit controller, which may be placed on a telegraph pole and thus be free from the shock and vibration to which a track instrument is subjected. Two opposite rail lengths are insulated, and wires from these rails and the adjoining uninsulated rails are led to the box containing the controller and battery, while live wires from the controller lead to the gong apparatus at the crossing, the current for which is supplied by a second and smaller battery. In another system, a Siemens armature (made of an iron spool wound lengthwise with copper wire) is arranged to revolve in the magnetic field of permanent horseshoe magnets, each revolution producing two impulses of electricity of opposite polarity, or alternating currents. The revolutions of the armature are produced by a fly-wheel train of gearing, which is operated by the recoil of powerful springs, these springs being compressed by the action of a hinged lever placed alongside the rail and depressed by every passing wheel. There is no battery, and the entire plant is out of operation except during the passage of the train and during the revolution of the fly-wheel by its momentum. The mechanism is placed in a box beside the track, 1,200 to 2,000 ft. in advance of the crossing.

Street crossings at yards and stations, where trains and switch engines are constantly moving to and fro, are often protected only by flagmen, who signal the drivers of vehicles when to cross. If there are many tracks, an open refuge place should be provided near the middle, so that teams need not wait until the entire crossing is clear. Such crossings, however, are extremely dangerous, especially in dark and stormy weather, when the drivers cannot see the flagmen distinctly, and the flagman's view is obstructed by smoke and steam. Ordinary street crossings have usually gates operated by watchmen. In rare cases "portcullis" gates are used, sliding vertically in high frames, while an arrangement has been suggested by which the gates would drop into deep narrow slots in the street. The most common form of crossing gate is a light wooden arm, swinging vertically and pivoted to an iron post near the curb, and being operated by gearing by means of a crank handle in the post. The sidewalk arms are operated by segmental racks on the shafts. The arms on both sides of the track are worked together, the connections being wires or chains led through pipes underground, while in one style of gate pipe connections are used, with bell cranks and levers as in interlocking plant. The arms are counterbalanced and may be fitted with targets and lamps. They are sometimes as much as 55 ft. long, with 35 ft. sidewalk arms where the tracks cross the street at an angle, but for wide streets it is common to use two arms on each side of the track. The gateman usually has a small cabin at the side of the track, or an elevated cabin like a signal tower, from which latter he operates the gates by means of levers. Gates of this kind should have a flexible piece at the end, opening upward and outward, so that if a team is shut in on the track it may be driven through, and thus perhaps avoid a serious accident.

Many gates of this kind are operated by compressed air from the cabin, by means of a hand pump, one or two strokes of the pump lever being required for each movement of the gate. The operating cylinders and mechanism are enclosed in the gate posts, which are connected by ¼-in. pipes. A pressure of only 7 lbs. per sq. in. is required, and the arms are

locked in either position. In one form of pneumatic gate a rubber diaphragm in an iron case is used instead of a cylinder and piston. One stroke of the pump operates the arm or arms on one side of the track, thus requiring two strokes to close the crossing and so reducing the liability to shut a team in on the track. One diaphragm of each pair closes the gates, and the other opens them, motion being transmitted by a rod, chain and bell cranks in each post, connected by rods underground. Automatic gates, operated from air pumps connected with a track lever, have been proposed, the air also operating signals and a gong apparatus.

At street crossings having tracks for horse, cable or electric cars, there should be provided some means of automatically stopping or derailing these cars if they run past a certain point when the gates are closed, as many accidents occur through carelessness or neglect on the part of car drivers, conductors and gatemen. The ordinary rule is that the car must be stopped and the conductor walk onto the crossing to see if trains are approaching, but he may be neglected, or his view may be obstructed by steam, smoke or moving cars. Derails or stop blocks, about 50 ft. from the crossing and interlocked with the gate, should be set in the street track, and for electric railways the current may be automatically cut off from the trolley wire for a short distance on each side of the crossing. This matter is further discussed in the following section on "Track Crossings."

Track Crossings.

Railway crossings at grade were freely adopted in the early days of railway construction, but it is now generally recognized that every such crossing is a point of danger and expense, causing more or less interference with traffic and increase in maintenance work, as well as an increase in fuel consumption where trains are frequently stopped. At small "know-nothing" or unprotected crossings, where all trains are required to come to an absolute stop, there is likely to be increased wear of rails due to the frequent stopping and starting and the use of sand. The extent of the wear will vary with the local conditions of grade, speed, traffic, etc. There is, therefore, a growing tendency to protect busy crossings by interlocking switch and signal plants, so that a train will not have to stop unless the right of way has already been given to a train on the other line. There is also a general tendency to eliminate groups of crossings near large cities, and enormous sums of money have been expended in the separation of grades, which expenditures have been fully warranted by the increased safety and freedom of traffic. Near Philadelphia, the four tracks of the New York and Philadelphia divisions of the Pennsylvania Ry. connected with the line leading to the Broad St. terminal station in such a way that all passenger trains had to cross the through main tracks at the freight yards, causing numerous delays, and also causing complication in handling the enormous number of freight trains at that point. This has been avoided by lowering the passenger tracks of the New York Division on a grade of 0.5% until they can pass under the yard at 1%, and then rising again by a grade of 1.2% to the normal grade. The crossing of trains at junctions, especially on four-track lines, has also been avoided in some cases by carrying one track over or under the normal grade. Such improvements not

only facilitate the traffic and ensure safety, but also reduce the expenses for maintaining crossings, switches, derails, interlocking plant, etc.

In the building of new railways there should be some legislative restriction upon the right to cross existing railways at grade, thereby interfering with the traffic of the latter and conferring upon it no corresponding benefit. The permission of the Railway Commissioners (or similar authority) should be required in each and every case, and should only be granted when the impracticability of separating the grades (or other good reason) can be proved. Unprotected crossings should only be permitted in exceptional cases, and the new railway might well be required to pay the entire cost of the construction and equipment of the crossing, including signals, interlocking plant, etc., subject to the approval of the existing line; and to pay also the expenses of watchmen, signalmen, and maintenance of plant. With such requirements, greater care would be taken to avoid such crossings, and there are comparatively few cases where they could not be economically avoided without much additional expense, especially if the continued expense for their operation and maintenance is taken into account. In some States (including New Hampshire, Massachusetts, Indiana, Ohio and Illinois), there are laws in regard to the avoidance and protection of grade crossings, of electric and steam railways as well as of steam railways alone.

The increased weight, speed and momentum of electric cars, and the numerous accidents and narrow escapes at crossings, have made it evident that the grade crossing of a steam and electric railway should be as efficiently protected as a crossing of two steam railways, and should be under the same state regulations. This is specially important in view of the great development of suburban and country lines of electric railway, on which cars run at high speeds, and the action taken by some States is much to be commended in putting a check upon this multiplication of dangerous grade crossings, and requiring over or under crossings to be made, or at least putting facilities in the way of providing such a separation of grades by permitting the condemnation and purchase of land for the diversion of an electric railway to avoid a grade crossing. Grade crossings of this kind call for more careful watching than grade crossings of steam railways and are really more dangerous, as the steam road claims the right of way, and the movement of cars on an electric road is liable to derangement without notice or apparent cause. Cases are numerous in which electric cars have in some way been deprived of power while passing over grade crossings. Interlocking plants may be used, it is true, but cannot ensure absolute safety, while they involve continual expense for maintenance, and their use may in some cases be almost impracticable, as when the electric line crosses switching tracks or a yard. In the construction of some electric railways intended for high speed service, considerable expenditures have been incurred in building diversions or viaducts purposely to avoid crossing steam railways at grade. This matter was discussed very fully in "Engineering News," May 18, 1899.

The construction of the crossing frogs has already been described, and it is, perhaps, best to rivet them to base plates, particularly where they carry heavy traffic, but the riveting must be good and substantial work or the rivets will work loose and the frogs will clatter. The rails and frogs may be

supported in either of three ways: (1) By ordinary ties placed at such angles as to afford the best support of all the rails; (2) Upon long switch ties or timbers; (3) By framed timbers which are halved together under the crossing frogs and give a continuous bearing to each rail. Where ties are used at a right-angled crossing they are usually laid at an angle of about

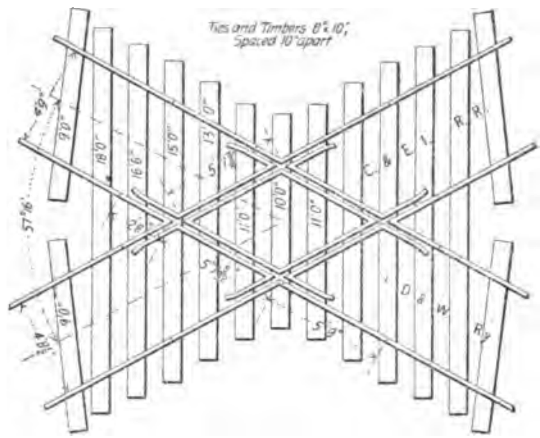


Fig. 96.—Track Crossing Laid on Ties and Long Timbers.

45°, but the arrangement cannot be anything but unsightly, and is inferior to the second plan. The third plan is the most substantial, especially for angles of nearly 90°, and it affords the best resistance to lateral shifting or creeping of the crossing. Where a main line crosses a minor line at right angles, one track may have a longitudinal timber about 6 × 10 ins. or 10 × 12 ins., 12 to 14 ft. long under each rail, while the other track has ordinary ties. Tie-plates should be placed on the longitudinal timbers.

The Chicago & Eastern Illinois Ry. uses ties and long timbers 8 × 10 ins., 10 ins. apart, for crossings of less than 75°, as shown in Fig. 96, and uses

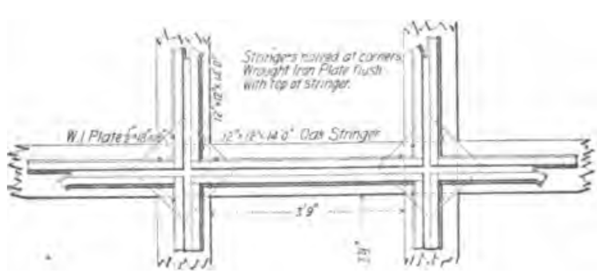


Fig. 97.—Track Crossing Laid on Framed Timbers.

framed timbers for other angles. The Chicago, Burlington & Quincy Ry. usually employs sawed ties, except at right-angle crossings, where framed timbers are used, as shown in Fig. 97. The New York, New Haven & Hartford Ry. uses frame timbers in all cases, but many roads use switch ties (about 7 × 9 ins., 8 ins. apart) for all crossings up to 80°. The earth

and old material should be dug out and replaced with broken stone or clean gravel to a depth of 12 ins. on banks, and even deeper in cuts where the drainage is bad, while tile drains are sometimes laid. It is very important to have a thoroughly good foundation at the crossing.

All important crossings should be equipped with interlocking plant for home and distant signals and derailing switches, but local conditions must govern the application of these switches, as in some cases they may be very dangerous. Every interlocking plant should have both home and distant signals. If an engineman finds the distant signal clear he knows he has the right of way over the crossing, but if he finds it against him he slows down and runs under control, expecting to be stopped by the home signal. The derailing switch should be not less than 300 ft. from the crossing on level track, and in Illinois the distance is now required to be at least 400 ft., on account of the increase in weight and speed of trains. On a double track line there should be a "backup" derail, 150 to 300 ft. beyond the crossing. The home signal may be 150 to 200 ft. from the crossing, and the distant signal 1,200 to 2,000 ft. from the home signal. The location of the signal and derails will depend upon the speed of trains, grades, etc., but the distant signal should be so far back as to give room for a fast train to be stopped before reaching the home signal, while the derail should be just beyond the home signal, but so far back that a derailed train will not be likely to reach the crossing. The derail may open to a short curved spur ending in a sand bank, so as to turn the train away from the crossing. It should be distinctly understood by all enginemen that the towerman is the man in authority at the crossing and can give the right of way to which train he pleases (subject to the general instructions given him), and the engineman has simply to look out for the signals and obey them implicitly.

Crossings of small country lines with little traffic are often left entirely unprotected, except by "slow boards" or signs. If near a station, there may be a gate or horizontal bar swinging around a vertical post, and having a target or lamp on it; one or other of the tracks being always blocked. Lifting gates, as used at road crossings, are also used in some cases, being so interlocked, that only one road can be cleared at a time. The protection of crossings of steam and electric railways has already been discussed. A simple interlocking system for grade crossings of main lines by smaller lines or electric railways, consists in equipping the less important track with derailing switches standing normally open, these derails being interlocked with the signals of the main track. In a system of this kind at a crossing of the St. Louis, Keokuk & Northwestern Ry. by a small single track line, the latter track is fitted with derailing switches, which must be held closed by a trainman to allow the train to reach the crossing. When a train on either main track reaches a point half a mile ahead of the Half automatic signal governing the block in which the crossing is located, it causes an indicator to be displayed at the derailing switches, giving warning of the approach of a train having the right of way. If the train on the single track finds that no main track train is approaching the trainman closes the derailing switch, and thereby sets the main track block signals at danger, thus showing that the crossing is occupied. (See also Chapter 14.)

CHAPTER 10.—TRACK SIGNS.

Various marking and warning signs are required along a line of railway, to indicate distances, boundaries, special points, danger points, etc., for the guidance of trackmen, enginemen, property agents, etc. In the case of reorganization or general improvement of railways, and the purchase or building of new lines, it is often necessary to establish a system of signs, or to reduce a heterogeneous variety of styles to some standard of uniformity. It will be appropriate, therefore, to give some consideration to the design and general practice in regard to track signs. The signs should be strong and durable, simple in design, economical in construction, free from ornamental molding or painting, of as few different styles as practicable, and designed specially with a view to being permanent, conspicuous and easily recognized. The signs which are for the guidance of enginemen should be set at a uniform distance from the rail, the length of post therefore varying on cuts and banks, but this cannot be universally observed. Mile posts, for instance, are often placed on the right of way, beyond the toe of the bank, instead of on the slope. These signs should be on the engineman's side (right-hand side) of the track, except where sidetracks or buildings interfere. They should never be less than 6 ft. clear from the nearest rail, and 8 ft. is a better distance, some roads specifying 6 ft. 6 ins. on embankments and 8 ft. in cuts.

The signs may be either simple posts, or posts carrying boards of various sizes. On many roads, posts of different sizes and shapes are used for a variety of purposes, and these signs have the advantages of simplicity and low cost, but they do not allow of as much lettering as is sometimes required; besides which they are not conspicuous enough for some of the most important signs. Boards or flat signs may be of wood, cast iron or sheet iron, the latter being sometimes enameled instead of painted. Wooden board signs are usually of 1-in. plank, and if of large size they should have battens about 1 × 3 ins. screwed to the back. Iron straps or wooden strips may be nailed to the ends of the board, but the use of molding strips as a frame is not to be recommended. The boards are generally nailed, screwed or bolted to the post, and are sometimes let into it, but this latter practice involves extra work. For a large board a strap or brace of wrought iron, ½ × 1 in., may be used, passing over the back of the post and having its ends secured to the ends of the board by ½-in. carriage bolts. Cast iron plates with raised letters or figures, are quite frequently used, being screwed to the posts. Small ones may be ⅜-in. thick, with rim and letters ⅝-in. thick, while large ones may be ⅝-in., and 1-in. thick. Cast iron posts with flat disk tops are very liable to be broken and cannot be repaired. A simple, cheap and effective sign has targets of heavy sheet iron fastened to posts of angle or tee iron or old boiler tubes, set in a base of concrete, sewer pipe, or burnt clay. Scrap material of little value can often be utilized to advantage in this way. Old rails are sometimes used for posts, depending upon their value as scrap. Stone, in the form of

posts or slabs, is sometimes used for mile posts, but rarely for any other signs.

The posts should be set not less than 3 ft. deep in the ground, and deeper if the sign is high or the board large. The lower end should be coated with pitch or creosote to about 12 ins. above the ground line. The top should be cut pointed, slanting or rounded, so as to shed water, and sometimes a piece of thin sheet iron is nailed upon the rounded top, but this is rarely necessary. Cast-iron caps are objectionable; they serve no useful purpose, and are liable to become loose and fall or be knocked off, being then often broken, stolen or lost. Broken stone or small field stone piled around the base of the post looks neat, protects the post from burning grass, and tends to keep weeds from growing. The edges of square posts may be chamfered, but no other decoration or trimming should be attempted.

There should be as little lettering as possible, and the letters or figures should be large, clear and plain. If much lettering is required, it is a good plan to have letters of malleable iron, about ¼-in. thick, screwed to the post, so that an ordinary track laborer can renew and repaint them. Otherwise a regular painter may have to be detailed to this work. Where a word is placed vertically (and this is a poor practice as a rule), it should read downwards if the individual letters are upright and upward if they are sideways. Caution boards with long worded warnings in small letters are of little practical use. They may serve to meet legal requirements in some cases, but nobody will stop to read them.

As to color, plain black letters and figures on a white ground is the most common practice, and is most conspicuous, but sometimes the lettering is white, on a black or blue ground. Two colors are usually sufficient for ordinary signs, but in some cases a third color is desirable for the back of signs, to render them inconspicuous. The third color may for the same reason be used for boundary and other signs which are not for the information of enginemen. Red and green, with white lettering, should be used for stop and slow signs respectively. White is in general the most striking color and should be liberally used. It is also the best color for signal posts, as the brown and dull ochre colors sometimes used are less distinct and tend to "kill" the brightness of the color of the signal blades. On the Atchison, Topeka & Santa Fe Ry., a brown mineral paint is used, except that where letters or figures are to be marked, the face is white with black border and lettering. The Chicago, Burlington & Quincy Ry. paints mile and section posts white, all other posts mineral red, boards white with black block lettering. Posts should be painted with coal tar to 6 ins. above the ground line. On the New York Central Ry., all signs are painted twice a year, in April and October.

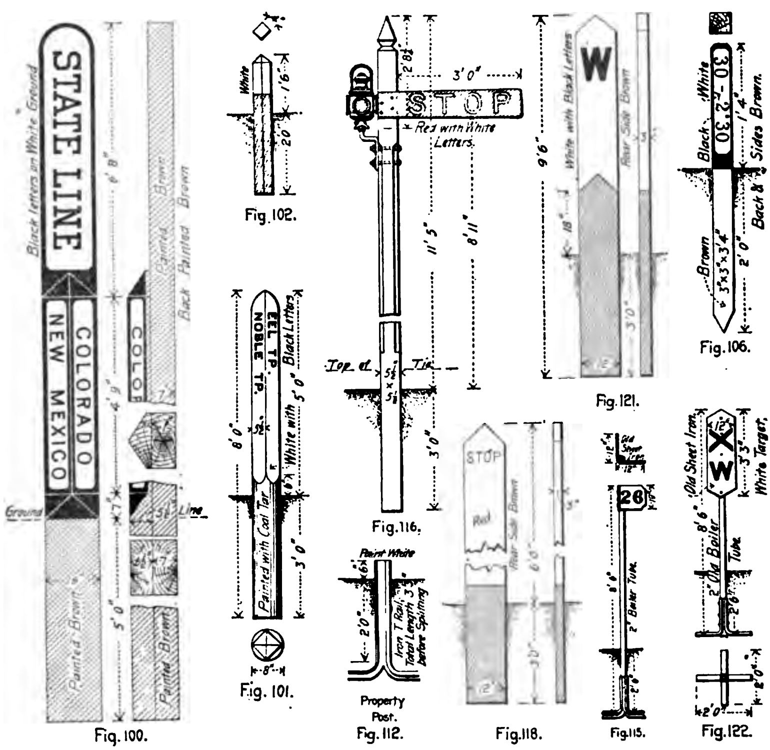
The signs used vary on different roads, but the principal ones are noted below. Besides these, there are such signs as "Shut this Gate," for farm crossing gates; "Keep off the Track," at bridges and streets where people are likely to trespass; "Derailing Switch in this Siding," placed at the head-blocks of sidings so equipped; and miscellaneous temporary or movable signs such as "Clean Ashpans Here," "Dump Ashes Here," etc.

Block Section Limit Signs.—With automatic block signals, the Cincinnati, New Orleans & Texas Pacific Ry. places a triangular sign 150 ft. in advance

of the signal and 9 ft. from the rail. The triangle is 3 ft. high, with its top 10 ft. above the rail. It is painted black, with white letters.

Boundary Posts.—The Atchison, Topeka & Santa Fe Ry. marks its crossings of State lines by a rather elaborate sign, Fig. 100. It is of oak, set 13 ft. from the rail and facing the track. County and township lines and city limits may be marked by round posts with faces flattened for the lettering, as in Fig. 101, which is that of the Pennsylvania Lines. Board signs are less frequently used.

Bridge Signs.—Bridges, trestles and large openings are usually numbered, for convenience of reference in regard to repair, etc. The number-



Track Signs.

ing should include every opening and waterway, however small, and where additional openings are afterwards provided, fractional numbers may be used. The structures or openings may be numbered consecutively from divisional points or by miles and letters, as 250A, 250B, etc.; indicating the first and second bridges beyond milepost 250. The numbers may be on iron plates or wooden boards; attached to the portals of through bridges, or to posts or ¾-in. iron rods, 4 ft. 6 ins. long, on the abutments of deck bridges or trestles. In some cases a wooden block of triangular section is spiked on top of the end of a tie, having the number marked on the inclined

Flanger Signs.—These are to indicate where the blades of snow plows and flangers are to be raised to clear switches, etc. The Northern Pacific Ry. uses a black board, 12 x 24 ins., 1½ ins. thick, let flush into a white post, 6 x 6 ins., with the top 8 ft. from the rail. The board is not lettered. This sign is for temporary use only, and is placed 8 ft. from the track, on the right-hand side, and 50 ft. in advance of the obstruction. Other roads use black with white disks, or yellow with black disks. On the Boston & Maine Ry., the signs are taken down in April and stored in the section tool houses. In November, the section foremen are notified to have them painted and erected.

Junction Signs.—The Atchison, Topeka & Santa Fe Ry. puts up signs 2,600 ft. from junctions, these being identical in style with its railway crossing signs above described, but lettered "Railway Junction."

Mile Posts.—These are commonly timber posts, about 10 x 10 ins., 8 ft. long, set 3 ft. 6 ins. in the ground and 12 ft. from center of track. The mile post of the Baltimore & Ohio Ry., Fig. 108, is of this style. The post is set either with one side or one edge towards the track, and may have the distance from (and the name or initial of) one or both of the terminal points painted on opposite sides. In some cases, where cheapness is specially desirable, small board signs may be nailed to the telegraph poles. The Northern Pacific Ry. sign, Fig. 109, is a post of barked cedar, set on the north side of the track, 8 ft. from the rail. Two boards, 2 x 12 x 16 ins. are let into the post at an angle of 60°, and have the names of the terminals of the division maked upon them, with the distances therefrom. The post and board are painted white, with black letters 3¾ ins. high and ⅝-in. thick, and figures ¾ x 5 ins., with a margin of at least 1 in. The Atchison, Topeka & Santa Fe Ry. uses a plate of ⅜-in. boiler iron, 10 x 18 ins., secured to the telegraph pole nearest to the exact distance by means of two lag screws ½ x 3 ins.

Stone mile posts are used by several railways. The Boston & Albany Ry. has square granite posts, Fig. 110, with two sides dressed down 3 ft. from the top, and pene-hammered. The cost, with one letter and three figures cut on each dressed side, is about $5 per post. The Lake Shore & Michigan Southern Ry. uses 10 ft. posts, Fig. 111. The Maine Central Ry. uses a rough dressed stone slab, 12 ft. long, 20 ins. wide and 8 ins. thick, set 4 ft. in the ground. It has 30 ins. at the top dressed smooth, and painted with three coats of white lead, with black lettering. The post is lettered on both sides, thus: "249 Miles to Vanceboro" on one side, and "2 Miles to Portland" on the other. The Ohio Division of the Erie Ry. uses flat stone slabs, with the letters cut into them. The slabs are set edgewise to the track and are painted white, with the letters and lower part black. Similar slabs, but of smaller size and less height, are used for half-mile and quarter-mile marks, but the use of such intermediate posts is not common in this country.

Premium Signs.—On roads having annual awards for condition of track, a sign is sometimes placed on the best section. A black board with "Premium Section" in gilt or yellow letters is a conspicuous sign for this purpose and may be erected on the section house or on posts at the section house or at a station on the section. There is no doubt that the men feel

proud of such a trophy, and will work hard to prevent another section gang from winning it away from them.

Property Post.—The marking of property lines or right of way boundaries should be done very carefully, and permanent monuments should be established. The Baltimore & Ohio Ry. uses a piece of rail, with the web split for about 6 ins., and the head and base bent out to form an inverted T, as shown in Fig. 112. The top projects about 6 ins. above the ground. The Lake Shore & Michigan Southern Ry. uses one of the best monuments that has come to the writer's notice for marking important land corners, etc.

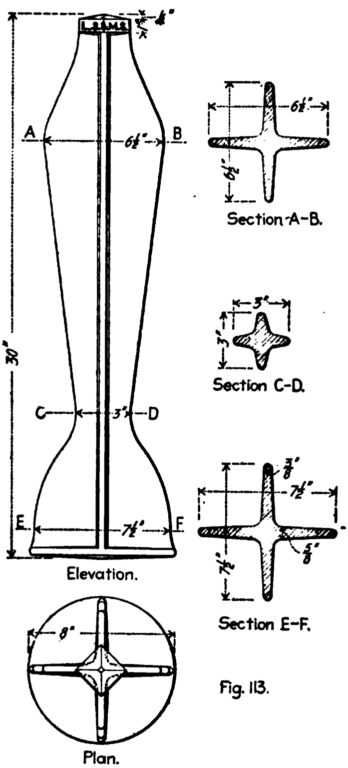


Fig. 113.—Property Monument; Lake Shore & Michigan Southern Ry.

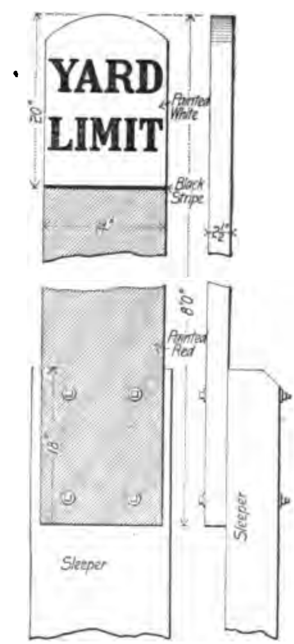


Fig. 123.—Yard Limit Sign; Maine Central Ry.

It is a cast-iron post, Fig. 113, with the section of a cross, and having a top cap 2 ins. square and a circular base. In the center of the cap is a ¼-in. hole, ¼-in. deep. All corners or angles in the boundaries of station grounds, etc., should be marked by posts, and if these cannot be set at the corners they should be set in the lines running thereto and have the distance plainly painted on the side facing the corner to be marked. These posts may be 8 ft. long, rough below ground, and 5 ins. square for the 3 ft. above ground. The Cincinnati, New Orleans & Texas Pacific Ry. uses pieces of old telegraph poles, 7 ft. long (3 ft. in the ground), placed at every corner and 500

ft. apart along the right of way line. They are painted white and lettered "Ry. Co. Right of Way," at the top.

Rail Signs.—On the same road, the make of rail and date of laying are indicated on a 12-in. disk set in the slot of a post, 2 ft. above the ground, 10 ft. from the center of the track. This is all black, with white letters. Other roads use stakes or small posts for a similar purpose.

Section Posts.—These mark the limits of track sections, and should be smaller and less conspicuous than signs to be observed by trainmen. On the Pennsylvania Lines West of Pittsburg, an oval iron sign, 10⅛ x 20¾ ins., is used, being secured by two bolts to the top of a post 4½ ins. square, Fig. 114. The plate has two panels sunk ⅛-in., with raised figures flush

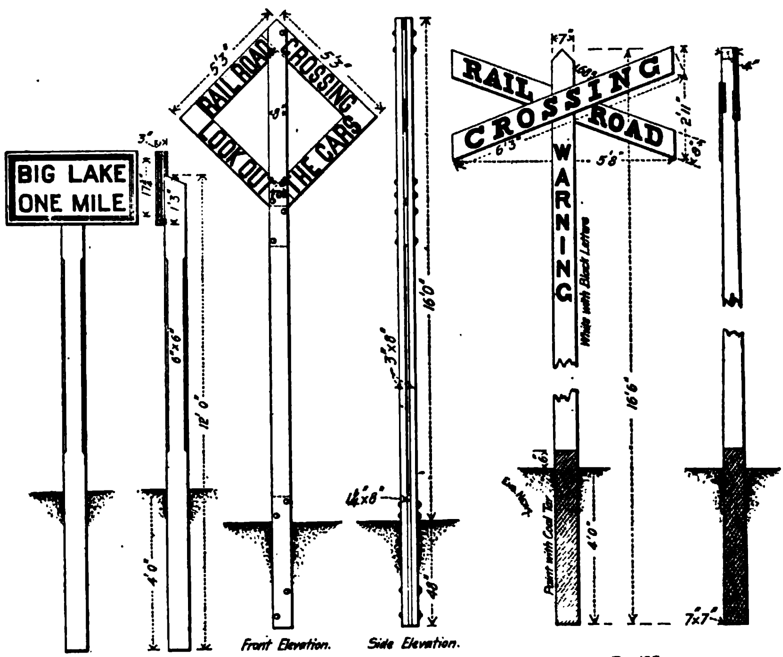


Fig. 119. Fig. 104. Fig. 103.

Track Signs.

with the surface of the plate. The panels are white; figures and face of post, black; post and back of casting, white; it is set 7 ft. from the rail. The Southern Pacific Ry. uses iron signs of the style shown in Fig. 115, having a target of old sheet iron, 10 ins. deep, bent to form two faces 10 x 12 ins. at right angles to each other, one of these facing the track. At its corner the target is fastened to the top of an old boiler tube by three rivets. The Northern Pacific Ry. uses a 1-in. board, 24 x 13 ins., with a frame ¾ x 2 ins., and nailed to a post 6 x 4 ins., 7 ft. long, set 3 ft. in the ground. The Atchison, Topeka & Santa Fe Ry. uses only an oak post 2 x 6 ins., 5 ft. long, set edgeways to the track, 6 ft. from the rail, with the section numbers painted on opposite sides.

Sidetrack Limit Sign.—On long sidetracks, for use by two trains, a square post like a mile post, but without figures, is placed to mark the middle of the sidetrack, for the guidance of enginemen.

Slow and Stop Signs.—These are used at the approaches to track crossings at grade, drawbridges, etc., and should be painted green and red, respectively, and lettered in white. They are usually either flat posts about 3 x 12 ins., or large boards on posts. Sometimes the boards are only 4 ft. above the ground, but a greater height is preferable. On the Pennsylvania Lines West of Pittsburg, these signs are made to conform to the standard position of signals. Thus, one has "Slow" in white letters on an inclined green arm; and the other (Fig. 116) has "Stop" in white letters on a horizontal red arm. The arms are 8 ins. wide, with 6-in. letters, and point to the right of the track. The posts carry switch lamps with green or red glasses. These signs are used where all trains must be under control, or come to a stop, the "Slow" sign being set 2,000 ft. from the danger point, while track crossings have the "Stop" signs at a distance of 300 ft. in each direction. Where only freight trains are required to be under control, a post 3 x 10 ins. is used, 6 ft. high above ground, painted green, with "F. S." in 8-in. white letters. The "Slow" board of the Atchison, Topeka & Santa Fe Ry. is shown in Fig. 117, and the "Stop" post of the Baltimore & Ohio Ry. in Fig. 118.

Station Signs.—A sign is usually placed one mile from each station, and whistle posts are also usually placed half a mile from the station, directing the engineman to whistle for the station. The distance should be measured from the outer switch of the station yard, or from the yard limits. A common style is that of the Northern Pacific Ry., Fig. 119, which is set 10 ft. from the rail. The board is 10 x 10 ins., 1-in. thick, with a frame 1 x 3 ins., and a 1-in. molding strip. The post and board are white, with black letters, frame and molding. The letters and figures are 5 ins. high, 1¼ ins. thick, with a 2-in. margin, and 3¼ ins. between lines.

Station Name Boards.—These should be large, boldly lettered, and conspicuously placed. No advertising signs should be placed near them, and no advertising signs of similar style should be allowed. They are frequently placed so that at night (or even by day) they cannot be seen from the cars, as, for instance, when they are placed on the eaves of the platform roof. They should be set back from the track, and have lamps specially placed to illuminate them, while it is also a good plan to have glass name slips in the windows of the agent's office, waiting room, etc. The sign should be not less than 18 ins. wide, the length varying with the name to be painted on it. The distances to the terminals or divisional points may be painted on each end of the board, before and after the name. White or yellow block letters on a black or dark blue ground are very prominent. Fig. 120 shows the station sign of the Atchison, Topeka & Santa Fe Ry., which is attached to the side of the building facing the track, with the bottom 8 ft. above the platform wherever practicable. Where there is no station building, the sign is bolted to two posts, 6 x 6 ins., 15 ft. long. The board is 12 ins. wide and ⅞-in. thick, with frame boards 1⅛ x 2¼ ins: It is an excellent plan to make the name of the station in large clear letters of white stones, shells, flowers, etc., on a turfed strip or a leveled surface of cinders just beyond the platforms.

Water Tank Signs.—At stations having water tanks for the engines, the words "Water Tank" may be painted on the one-mile station sign, while for tanks between stations a special board sign with "Water Tank, One Mile" (or "½ Mile"), may be put up. The ends of track tanks are usually marked by green targets, mounted on iron rods, which also carry green switch lamps at night. This is to indicate to firemen when to lower and raise the tender scoop, the latter signal being placed about 100 ft. from the end of the tank.

Whistle and Ring Signs.—These are usually set ¼-mile on each side of the road crossings and ½-mile or 1 mile from stations, placed on the engineman's side of the track. They may be flat posts, 10 x 4 ins., set with the edge to the track and having the top cut to a point or rounded. Fig. 121 shows the Baltimore & Ohio Ry. post. Square posts, 8 x 8 ins., are also used. The length is from 8 to 12 ft., with 5 to 8 ft. above ground, the higher ones being used where deep snows occur. The posts are usually white, with a large black R or W (or both) 6¼ ins. high, the sides and back being sometimes painted light blue, so as not to be conspicuous. In some cases the face is cobalt blue with white letters, or brown with a white panel

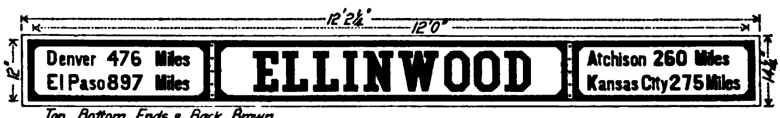


Fig. 120.

Fig. 120.—Station Name Board; Atchison, Topeka & Santa Fe Ry.

and black letters. A simple sign, made from scrap, is that used by the Southern Pacific Ry. for road crossing whistle signs, Fig. 122. It is painted white, with black letters. The X on this sign is to indicate that it is a crossing sign, and some roads put "S. W." on the station whistle posts. For a post 10 or 12 ins. wide, the letters should be about 9 ins. high and 8 ins. wide, with lines 1½ ins. thick; plain block letters should be used. "Whistle and Ring" signs (lettered W. R.) are used at places where it is necessary to give warning to track and bridge men of the approach of trains; these should be 1,000 ft. distant from the point to be warned.

Yard Limit Signs.—These denote the limits covered by the yard gangs, and to which switching engines work. All trains (except those of the first class) are usually required to stop at them before entering the yard, unless the track is plainly seen to be clear (see Chapter 12). The Chicago, Burlington & Quincy Ry. uses a board 24 x 38 ins., on its standard post, with the name of the station: "Aurora; Yard Limit." On the Pennsylvania Lines West of Pittsburg, is used an oval cast-iron sign, 33½ x 20 ins., 4 ft. 6 ins. above the ties; it is painted green, with white letters. The Maine Central Ry. sign is shown in Fig. 123.

CHAPTER 11.—WATER AND COALING STATIONS AND OTHER TRACK ACCESSORIES.

Tanks and Water Supply.

The construction and maintenance of these structures and of all fittings pertaining to water supply frequently come more or less under the charge of the track department, and may be considered here. The quality of the supply is a very important matter, affecting the life of the boilers and the steaming capacity of the engines, and, therefore, the expense of operating and maintaining the motive power. It is rarely given much thought in location, however, the only consideration then being to get water, regardless of quality. Good boiler water is rather exceptional, and if it is not obtainable from natural sources then chemical treatment should be adopted, the water being treated before it is delivered to the engines. The principal trouble is hardness of the water, with scale-producing properties. The character of the water varies so much that each supply must be tested and the proper treatment prescribed, some simple means being adopted by which the proper proportions of chemicals can be used by the man in charge of the station. Heating the water in the station tank by a steam coil will cause the water to throw down much of the matter held in solution. Sedimentation and filtration may also be required for dirty water. The treatment (chemical or mechanical) need not involve much expense, and will effect great economy in reducing the cleaning and repairing of locomotive boilers, and increasing their life. A report on this subject is contained in the Proceedings of the American Railway Master-Mechanics Association, 1899. Several roads employ soda-ash (carbonate of soda) and lime water, mixed with the water in an auxiliary tank, and then added to the supply in the main tank. The Baltimore & Ohio Ry. has employed soda-ash (carbonate of soda) to neutralize the acids in the water. The solution is placed in a small tank connected with the supply pipe to the main tank, the quantity of soda-ash being varied according to the depth of water in the main tank. The Union Pacific Ry. has used tri-sodium phosphate for neutralizing sulphuric acid in the water. In some chemical plants there are two tanks, one above the other. The water is first pumped to the upper tank, passing through a chamber containing chemicals, and is there stirred mechanically. After settling, it passes to the lower tank, ready for the engines, and the upper tank is again filled. The character and amount of chemicals, and the cost of treatment, depend largely upon the the character of the water. In consequence of a bad local water supply, the Long Island Ry. established a pumping plant of 2,000,000 gallons daily capacity and a pipe line of 8½ and 10-in. pipe to supply the tanks, etc., at Long Island City from wells 10 miles distant. Such a practice may sometimes be adopted with advantage, the cost of establishing and maintaining the plant being more than offset by the reduction in engine expenses, etc., incident to the use of bad water. In districts where the supply is scarce and uncertain, improvements have been made by damming streams

to form large reservoirs, thus ensuring a permanent and abundant supply and often a better quality of water, while in some cases it also does away with the necessity of hauling tank cars to supply the engines and stations.

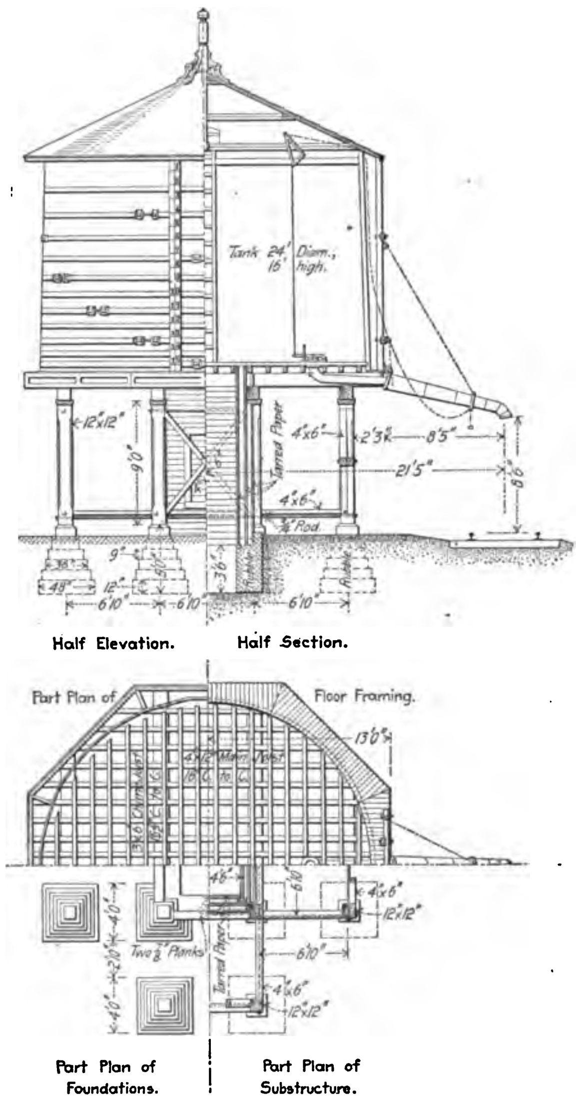


Fig. 124.—Water Tank for Supplying Locomotives.

The most common form of tank is of wood, with vertical staves, bound by iron bands and supported on a masonry tower, or upon trestle towers of wood or steel. A very general size is 16 ft. high and 24 ft. diameter, with a

capacity of 50,000 gallons. Steel tanks are used to some extent, but for capacities up to 100,000 gallons wood is very generally considered to be more economical, being cheaper and more durable. Where steel is used, the tanks are sometimes in the form of standpipes, their construction being cheaper than elevated tanks on steel towers, and allowing ample space for sediment. On the Chicago, Rock Island & Pacific Ry. there are standpipes 12 and 20 ft. diameter, 40 to 60 ft. high. Those on the Atchison, Topeka & Santa Fe Ry. are of the same heights, 24 ft. diameter, with capacities of 96,000 and 202,000 gallons or 57,700 and 163,800 gallons above the outlet, the spout being 12 ft. above the rails. The level of water in the tank is shown by a float connected to a ball sliding on a staff above the tank or to a pointer moving on a vertical graduated scale fixed to the side. The supply pipe leading up the tower to the tank is usually boxed in as protection against freezing. A steam pipe may be led into this chamber, or a stove may be placed therein. During extremely cold weather the section foreman is often called upon (through the roadmaster) to furnish a man to look after the water station. All the pumps, pipe connections, valves, tanks and other equipment, should be thoroughly examined at least once a year, and a special examination made before winter to see that all outdoor work is tight and properly protected against freezing.

Where engines take water directly from the tank, a horizontal pipe from the bottom leads to a hinged spout which may be let down to enter the manhole of the tender, but is counterweighted to stand vertically. It is pulled down by a chain within reach of the fireman standing on the tender, who also operates the valve by means of a chain or lever, or it may be operated from a handwheel on a stand on the ground. This system of supply, with a wooden tank on a wooden tower, is shown in Fig. 124. When the tank cannot be placed close to the engine track, or where engines on several tracks have to be supplied, two tanks may be connected by a horizontal pipe crossing the tracks and having a hinged spout and valves over each track. The usual practice, however, is to place water columns or standpipes beside or between the tracks. The water column consists of a vertical stationary pipe, with a horizontal swinging arm, which should be so mounted as to lie normally parallel with the track, its end being over a catch basin with grated top. The arm may be hinged so as to reach down to the tender, or it may have a leather hose or adjustable vertical spout on the end. The position of the column in relation to the track and catchbasin is shown in Fig. 125. Many water stations have too small a discharge so that fast trains are delayed unnecessarily in taking water. The standard plan of the Chicago & Northwestern Ry. is to use tanks 16 x 24 ft., on towers 16 ft. high, with a 14-in. main to a 12-in. water column. Tanks have been put 20 ft. high for supplying 10-in. and 12-in. standpipes and with the latter a discharge of 4,000 gallons per minute may be obtained, but care must be taken to avoid elbows in the pipes, as they greatly reduce the capacity. The Baltimore & Ohio Ry. uses 50,000 gallon tanks, 20 ft. above the rail, with 8-in. mains supplying 8-in. columns (30 to 40 ft. distant), the discharge being about 1,200 gallons per minute. It is proposed, however, to increase the size of main and standpipe to 12 ins. thus greatly increasing the discharge. The new water stations of the Chicago & Alton Ry. have 90,000-gallon tanks, 20 ft. above the rail, with 14-in. mains and 12-in. water columns, having

a discharge of no less than 5,000 gallons per minute. The Lake Shore & Michigan Southern Ry. supplies the water columns from tanks on 30-ft. wooden towers, the center of which is enclosed by a 12-in. brick wall to form a chamber for the pipes. At tanks and columns, provision must be made to prevent leakage, or in winter there may be an accumulation of ice over the rails which may perhaps cause a derailment.

In the water column, which is shown in Fig. 126, the pipe is supported by a high base casting, and is automatically latched when the

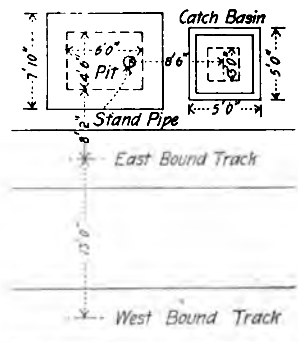


Fig. 125.—Location of Water Column.

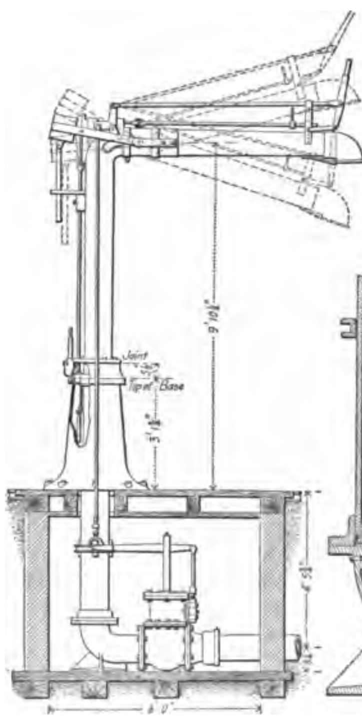
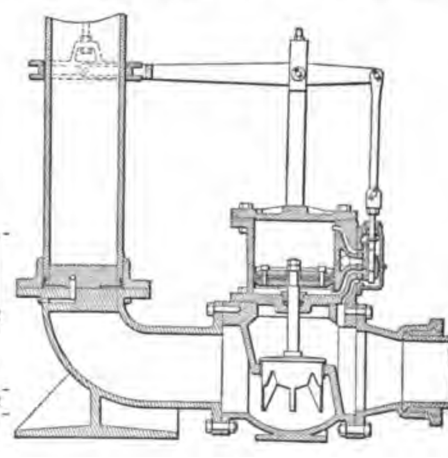



Fig. 126.—Water Column.

arm is parallel with the tracks. The latch may be locked by a switch lock. The spout has a joint of vulcanized rubber, except in large sizes, where the force of the water would make it difficult to hold the spout down in the manhole. The weight of the spout is carried by a wrought iron hinge, with counterbalance. The valve may be operated by a handwheel on the end of the spout, to prevent shutting off the water too suddenly. A relief valve may be provided where the pressure is heavy or an air cushion to absorb

the shock due to water hammer if the valve is closed too quickly. In the pipe shown in Fig. 126, the main valve is operated by the water pressure and not by hand. The piston in the hydraulic cylinder over the valve has an area considerably larger than that of the valve, and the flow of water to and from the cylinder is controlled by a slide valve operated from the lever on the end of the spout. The exhaust is controlled by a small stop cock which can be set to secure slow closing of the valve if required.

The water supply may be delivered to the tanks by pumps driven by wind, gas or steam engines. Gasoline engines are in many cases preferable to and more economical than steam, as shown by reports presented at the meeting of the American Society of Railway Superintendents of Bridges and Buildings in 1899. On the Chicago & Eastern Illinois Ry., the cost per 1,000 gallons pumped at different stations ranged from 1.70 to 2.27 cts. with gasoline engines, and 2.96 to 3.57 cts. with steam. The economy varies with the cost of coal, and is largely in the reduced labor for attendance. Windmills have wheels 8 to 30 ft. diameter, running at 54 to 26 revolutions per minute, and operating pumps of 2 × 4 ins. to 10 × 24 ins. The delivery per stroke is as follows:

Ins.	Gallons.	Ins	Gallons.	Ins.	Gallons.	Ins.	Gallons.
2 × 4	0.052	3 × 6	0.178	4 × 8	0.422	6 × 15	1.814
2½ × 5	0.102	3½ × 7	0.284	5 × 10	0.835	10 × 24	8.040

The pumps for railway service usually have a stroke of 6 to 18 ins. With double acting pumps, the delivery will be doubled. The diameter of the pipes should be half that of the cylinders, or rather larger for double acting pumps. The capacity of some standard sizes of Knowles steam pumps for this class of work is as follows:

Cylinders						Pipe			
Steam, ins.	Water, ins.	Stroke, ins.	Delivery per stroke, gallons.	Strokes per minute.	Delivery per minute gallons.	Steam, ins.	Ex-haust, ins.	Suction, ins.	De-livery, ins.
6	6	12	1.47	100	147	¾	1	4	4
6	7	12	2.00	100	200	¾	1	5	5
7½	7½	10	1.91	100	191	1	1¼	5	5
8	7	12	2.00	100	200	1	1¼	5	5
8	10	12	4.08	100	408	1	1¼	6	6
10	12	12	5.87	100	587	1¼	1½	8	6

An automatic arrangement has been invented by Mr. McHenry, Chief Engineer of the Northern Pacific Ry., to do away with the pumping engines. At the bottom of a well is placed a closed tank of rather greater capacity than the average tender tank, and in this is a float or loose piston. From the bottom of the tank a pipe leads to the water column, which has no valves, while another pipe extends to a steam standpipe, from which connection is made to a pipe on the engine. When steam is turned on, the float is forced down, and forces the water through the pipe to the water column and tender.

Track Tanks.

In order to enable trains to make long runs without stopping, means must be provided for supplying the engine tenders with water, and for this purpose track tanks are used, being shallow tanks laid upon the ties between the rails. A vertical pipe with its end terminating in an elbow is placed in the tender tank, and extends through the bottom, its lower end being fitted with an adjustable hinged "scoop," which is lowered about 3 ins. into the water while the engine is running over the tank. The speed of the engine

forces the water up the pipe into the tender, and water can be taken at 60 miles an hour. The scoop is operated by the fireman by means of a lever, and is counterbalanced against the water pressure. This system was invented in England by Mr. J. Ramsbottom in 1861. The purpose is mainly to save time, and the system is specially adapted for fast passenger and freight service, except in regions where permanent water supplies are few and far between. The track tanks are usually 25 to 30 miles apart, and are supplied by direct pumping or from elevated water tanks.

The track tanks of the Michigan Central Ry., Fig. 127, are about 1,400 ft. long, 19 ins. wide and 7 ins. deep. They are of 3-16-in. steel, with a half-round 1¼-in. stiffening bar along the upper edges, and an angle iron 1¾ × 1¾ × 3-16-in. to support them on the ties, which are 8 × 8 ins., 8 ft. long, boxed out to fit the bottom of the tank. Water is supplied by a pipe entering at the most convenient point through a box riveted to the bottom of the tank, from which it flows through a 5-in. orifice into the tank. Branch pipes to admit steam to prevent freezing in winter are placed about 40 ft. apart along the entire length of the tank, and the construction of the ½-in. brass nozzle is such as to throw the jet of steam downward. With very cold weather, however, steam jets are not sufficient to prevent the formation of ice, and on the Chicago, Milwaukee & St. Paul Ry. a cir-

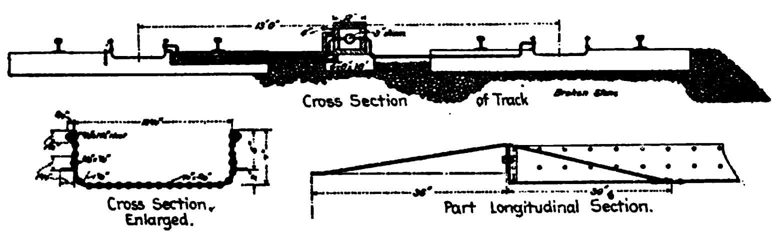


Fig. 127.—Track Tanks; Michigan Central Ry.

culating system has been introduced. At the mid length of the tank a 5-in. pipe enters the bottom, and forms the suction pipe of a steam pump. From the pump the water is forced into an 8-in. return pipe, into which is led a 1-in. steam pipe from the boiler. From the end of the return pipe two 3-in. pipes are laid parallel with and leading to each end of the tank, the water being discharged behind the inclined iron apron which raises the scoop in leaving the tank if the fireman has not raised it in time. The pipes are all laid in square boxes of 2-in. plank. This combination of heating and circulation has proved successful at 20° F. Men must be employed to clear the rails from ice formed by the spray and spilling of water.

The Baltimore & Ohio Ry. in 1890, adopted a very fast schedule between Philadelphia and Baltimore (1 hour 47 minutes for 92 miles with heavy trains), and two track tanks were put in, dividing the distance into three sections of about 30 miles each. These tanks were planned and built under the direction of Mr. G. W. Andrews, Superintendent of Bridges and Buildings. The troughs being 1,200 ft. long, it was necessary to make the track level for that distance, running off easily at each end to regular grade. This work was done by the regular track force. At Tank No. 1 it was necessary to

raise 17 ins. at one end, including a double-track through-truss bridge of 115-ft. span. Tank No. 2 was on a bank, where grades of 0.2% formed a dip of about 4 ft. The grade having been leveled, the hewed ties were replaced with sawed ties of white oak, 8 x 9 ins., boxed 1½ ins. x 19 ins. for the tanks, but some roads using high and heavy rails now lay the tanks on the face of the ties. The tanks are 6 ins. deep, 19 ins. wide, made of 3-16-in. steel sheets, 15 ft. long, with an angle iron 1½ x 1¼ ins., riveted to each side, 1½ ins. from the bottom. These rest upon the ties and the tanks are fastened to the ties by ordinary track spikes, the heads of which catch on the angle iron. This allows the tanks to expand or contract, but they are fastened firmly at the centers. They were made in 30-ft. sections in the shop. In laying, each joint was red-leaded, and cold riveted with 0.7-in. rivets, 20 to the joint. At each end is placed an inclined plane, with a total length of 13 ft. 8 ins.; the inner end of this is riveted to the bottom of the trough and the outer end fastened to the tie by means of rail spikes driven at the edge of the plate, with heads of spikes resting thereon, thus allowing for expansion of the trough. The object of this plane is to force the scoop on the tender of the locomotive up into position to clear the tank should the fireman fail to raise it, thus preventing any damage either to scoop or tank.

At Tank No. 1 it was necessary to construct a dam 6 ft. high and about 75 ft. wide. From the reservoir the water is drawn through a 6-in. cast-iron pipe a distance of 600 ft. by means of a steam pump, and forced into a tank of 40,000 gallons capacity, placed 28 ft. above the track. At Tank No. 2, the supply flows by gravity from a mill race about 600 ft. distant to a filtering well at the pump house, and from this it is forced by a steam pump into a tank of 50,000 gallons capacity, 28 ft. above the track. These tanks are circular, with hexagonal roofs, covered with slate. The staves and bottom are of 3-in. white pine, the whole bound with 11 hoops of iron 3-16 x 4 ins. These tanks are always kept full, and from them the water is delivered to the track troughs in the following manner. An 8-in. cast-iron pipe is connected to the elevated tanks, and run to a point at or near the pump, where it is reduced to 6 ins. At this point is placed a 6-in. gate valve. The supply pipe, running direct to the trough, branches off to three points by means of tees, reduced at the point of leaving the valve to 3½ ins. Two of the branches are connected to the troughs at points 200 ft. from the ends and the third is connected to the center of the trough. At the points of connection of the water-pipe to the trough there is built a pit the full width of the track, about 3 ft. wide and 3 ft. 6 ins. deep, with the side and end walls of masonry; the top is covered with 2-in. plank, and the bottom drained to one side. Into these pits the pipe is run, and it is connected to the trough by means of a 3½-in. pipe flange, nipple and metal expansion joint. These expansion joints were made in 1890, and are still in good condition (1900). The only repairs required have been slight repairs to the packing. Some roads have used a rubber hose in place of an expansion joint. At this point is placed a 3½-in. globe valve for use in emptying the troughs for cleaning or repairing.

In order to keep the tanks free from ice during cold weather, a 2½-in. pipe is connected to the steam dome on the boiler in the pumping station, whence it is carried to the center of the tracks on double track, or to the ends of the ties on single track. There the pipe is reduced to 2 ins., and

run to a point 5 ft. from the end of the trough. On this pipe at intervals of 45 ft. is placed a cross, from which a 1-in. pipe is carried to the troughs. This connection is made with a nipple of extra strong pipe, cut 3 ins. long, tapped out at one end and plugged with a ⅛-in. hole, inclined downward. Immediately back of this nipple is placed a 1-in. check valve to prevent the back flow of water when steam is turned off. The 2-in. pipe in the center is drained from both ends with a drain cock placed at the lowest point. To prevent breakage through expansion or contraction, expansion joints were placed at intervals of 200 ft. All steam pipe should be boxed in and packed with mineral wool or covered with magnesia or asbestos pipe covering, to reduce the condensation. The pressure of steam necessary to prevent freezing in the coldest weather was found to be about 80 lbs. During the warm months, when steam is needed for pumping only, an upright boiler of 25 HP. is used. During cold months, when it is necessary to have steam constantly in the troughs, an old locomotive boiler of about 80 HP. is used at each station. Each is, of course, connected to both its boilers. At these, as well as at all other water stations on the Philadelphia Division, a No. 9 Blake pump is used, with a capacity of 260 gallons per minute. This system of heating has been in use for ten years, and has been tested by extremely cold weather, but none of the troughs have been frozen up.

At the end of a trough nearest the approaching train is placed a signal similar to a high switch stand. This is to notify enginemen and firemen where to lower the scoop. At 100 ft. from the far end is placed a similar signal, at which point the fireman is supposed to raise the scoop, providing he has not filled his tank before reaching that point. As already mentioned, a 6-in. valve was placed in connection with the supply pipe at or near the pump house. Over these valves is built a small valve house, with its floor about on a level with the track. After an engine has taken water these valves are opened and water is allowed to run into the trough for from four to six minutes. When these tanks were first put in use there was considerable complaint that the troughs were often not more than two-thirds full. On investigation it was found that freight trains running over the trough had thrown out considerable water by the current of air caused by the passage of the cars. The pumpmen were, therefore, instructed to inspect the troughs five minutes before schedule time of trains; to see that they were properly filled; and to remain in the valve house from that time until after the train passed. The cost of these track tanks was as follows:

	No. 1.	No. 2.
Preparing roadbed	$1,094	$2,767
Labor (placing trough, running pipe, etc.)	2,135	1,549
Trough (including all shop work)	4,159	4,159
Hauling	61	80
Material (including ties, pipe fitting, pipe)	2,939	3,030
Total	$10,388	$11,535

Labor includes all labor in the field except grading. Included in each cost is the running of 8-in. cast-iron pipe (75 ft. for No. 1 and 600 ft. for No. 2) and placing two water columns for the use of freight engines. The cost of operating each station per month is $132.50 (2 pump men at $45, $90; coal, 15 tons, $22.50; ordinary repairs, $20).

Coaling Stations.

Coal may be loaded onto the engine tenders in various ways, according to the location, the number of engines to be supplied, and the ideas of the officers, but in any case the structures and apparatus are usually more or less under the care of the track department. The coal should be handled as little as possible and given as little of a direct drop as possible, so as to avoid breakage of the coal and the expenses due to rehandling.

The coal may be delivered into the tender by either one of four principal methods: (1) Hand shoveling from a coal stage; (2) Buckets handled by a crane on the ground or on a coaling stage; (3) Dump cars running on a coaling stage beside or above the track; (4) Elevated chutes. These general plans admit of various combinations and modifications. The coal may be shoveled from gondola cars or dropped from hopper bottom cars onto the storage space on the ground or at the back of the coaling platform, and then either shoveled directly into the tender, or into buckets or cars which are wheeled to the crane or to the dumping track on the edge of the platform. For an important station the coal is usually stored in piles or bins and removed as required to the loading tracks by various forms of mechanical conveyors. On elevated or suburban lines using tank engines with small bunkers, a drop-bottom bucket is sometimes used, swung on the end of an arm operated by power. The bucket is not opened until it is swung down close over the bunker, so as to avoid dust and waste.

The coaling station of the Pittsburg, Cincinnati, Chicago & St. Louis Ry., at Chicago, has a coaling stage or trestle 130 ft. long, with 46 ft. of straight track for unloading. The dump cars are of 5,000 lbs. capacity, 5 ft. long, 8 ft. 10 ins. wide and 2 ft. 4 ins. deep, the back being over the inner wheels and the front projecting over the edge of the trestle. The body is pivoted over the sill nearest the edge of the trestle, and is held by a hook or latch at each end, while a rod under the body operates an iron apron which is lowered automatically as the car tips. This directs the coal properly into the tender, and avoids the use of fixed chutes or aprons on the platform. The cars are run from the loading place to an elevator at one end of the platform (on which they are weighed automatically while ascending), then pushed by hand to the point where they are to be discharged, and then onto another elevator by which they are lowered to the ground, where a down-grade track carries them automatically to the loading place.

Where coaling chutes are used, they may be on a bridge over several tracks or in the side of a shed with a coaling track on one or both sides. In some cases small cars are wheeled by hand from the coal pile and dumped at the chutes, but the better and more common plan is to have bins or coal pockets behind the chutes. These pockets may be filled directly from coal cars run into the coaling trestle (up an approach grade of 5 or 6%), but at large stations they are usually filled from the storage piles or bins by tubs running on a cableway or by a conveyor consisting of an endless chain with blades or scrapers running in a trough. Transverse troughs fitted with gates control the discharge into the various pockets. These pockets may have a capacity of 3 to 5 tons each, and should be charged with different quantities so as to deliver any desired quantity to the engine.

In Fig. 128 is shown the construction of a coaling station fitted with the Burnett & Clifton chutes. The floor of the pocket is covered with No. 12 sheet steel and is at an angle of about 35° with the horizontal for bituminous coal, while anthracite will slide on a somewhat flatter angle. The door which retains the coal in the pocket is of oak, and is latched or unlatched by the movement of the apron. This apron, which may be of wood or iron, serves to direct the stream of coal into the middle of the tender, and when not in use swings up to a vertical position, covering the door of the chute. The apron is pulled down by the fireman by means of a chain, and is balanced by arms which extend to the rear and carry an iron balance whose weight slightly exceeds that of the chute, so as to return it automatically to position when all the coal has run out. This avoids the use of chains and pulleys for counterweights. In the construction of a system of pock-

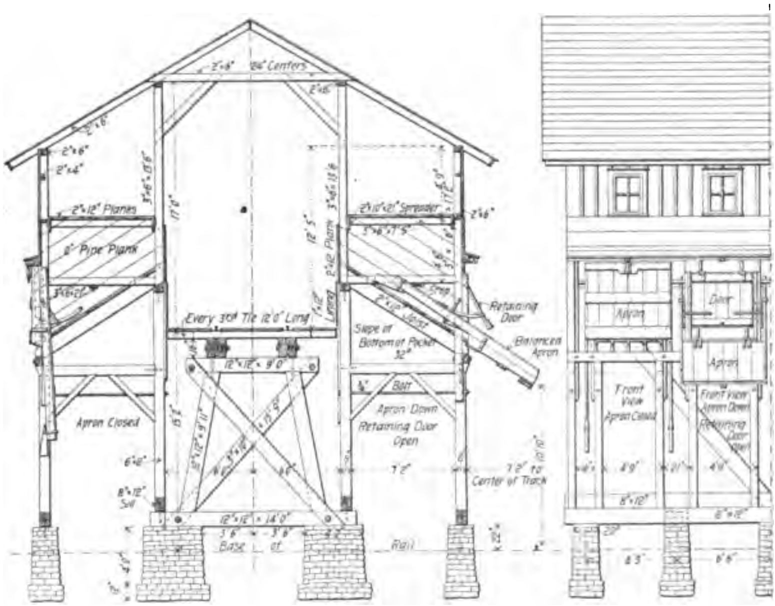


Fig. 128.—Coaling Station.

ets, strength, durability and reliability must be carefully looked after The rough handling, and the dirt and dust are likely to cause any complicated mechanism to get out of order, but it is necessary to have the opening and closing effected easily and quickly.

Ashpits.

A common arrangement where engine ashpans are cleaned, is to run the engine over a brick-lined pit, dump the ashes, and then shovel them up onto the ground and then into cars to be hauled aways. In some cases small cars or buckets run on a narrow gage track in the pit, and are han-

dled by a crane, the cars receiving the ashes as they drop from the engine. The shoveling of ashes is unpleasant and expensive work, and should be reduced as much as possible. If the engine track is raised or the cinder car track is depressed, so that the floor of the pit will be somewhat higher than the sides of the cars, the ashes will merely have to be shoveled to the side instead of being lifted. One side of such a pit can be left open and the floor inclined, so that the ashes can be shoveled readily into the car; or iron chutes may be provided, down which the cinders will fall direct from the engine to the car, a water jet being used to wash down the heavier parts. Conveyors may also be used where space is limited and the ashes from a large number of engines have to be handled.

With narrow pits, the rails may rest on wooden stringers on the side walls. With wider pits, they may be carried on wooden or iron stringers resting on iron columns or brick piers. Two 15-in. I-beams, under each rail, bolted together and connected by tie-rods, make a substantial support for the track, the span being about 15 to 20 ft. The rails may be attached by bolts, or keyed in iron chairs. The ironwork, brick walls (of narrow pits) and piers, and wooden stringers, should be protected from contact with hot ashes by sheet-iron coverings. The pit at the Burnside shops of the Illinois Central Ry., Fig. 129, is 80 ft. long. It has the outer rail car-

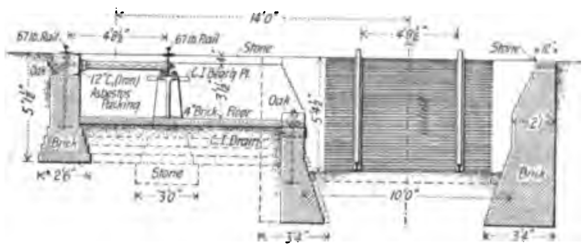


Fig. 129.—Ashpit; Illinois Central Ry.

ried on a 12 x 16-in. oak timber on the side wall, protected by a channel iron with asbestos packing; and the inner rail is carried on a line of 12-in. I-beams supported by cast-iron pedestals 10 ft. apart. These beams are bolted through to the timbers by 1¼-in. rods, with 4½-in. sleeves. The floor is of firebrick and has an oak fender 8 x 13 ins. A pipe is laid on each side of the pit and provided with cocks to supply water for cooling the cinders and washing the pit. The pit at the Chicago (27th St.) yards of this road has a grated bottom covered by removable iron plates, with a spiral conveyor running below the grating. When the ashes are quenched, the plates are removed, and the ashes fall through to the conveyor. Pits 16 to 20 ins. deep, with rails on longitudinals, and having an iron lining for the bottom and sides, are sometimes used, particularly on elevated railways.

Turntables and Transfer Tables.

Turntables usually have a pair of fish-belly or parallel-chord deck girders (cast or built up), though through and half-through girders are sometimes used when a shallow pit is desired. The tables are 60 to 75 ft. long, built for engines and tender loads of 100 to 150 tons. New tables should

be long enough and strong enough to take the largest and heaviest engines, should be well braced to resist racking, and should swing true and steady, it being borne in mind that they have heavy work to perform, and are often roughly used and indifferently cared for. The bearings, wheels and track should be carefully looked after, especially in roundhouse tables, as any failure of such a table may tie up all the engines. When turned by hand, two men bearing against the levers ought to be able to operate them readily, but in some cases gearing operated by crank handles, or by pneumatic or electric power is used. In many cases a little pony truck running on the turntable rail is operated by electricity and hauls the table round. Power operation is very desirable where many engines have to be turned, on the score of economy in time and expense, and in one case the use of an electric pony truck reduced the cost of operation from $7.37 to $3 per day. The pit may have a dished bottom, paved with brick, but the more usual plan is to have a flat bottom, and to form a step or bench in the side wall to carry the circular track. The masonry should be of substantial construction, and the pit should be well drained, and kept free from weeds and refuse. It is usually open, but sometimes covered by a circular deck, though this is likely to result in a damp and dirty pit.

Turntables are of two general types: (1) Those which have a center bearing or pivot and a rim bearing of wheels running on a circular track at the circumference of the pit; (2) Those which swing entirely from the center. The Erie Ry. has a 65-ft. table of the first type which is operated like a drawbridge, the drum being 8 ft. 2 ins. diameter and resting on 32 cast steel rollers. The ends have a rocking movement of ¾-in. A 15-HP. electric motor is placed vertically against the drum, and operates a train of gearing which ends in a pinion working in the fixed circular rack. The wires are carried up through the center. The Strobel turntable is of the second type, having a horizontal faced ring which bears upon a live ring of conical rollers on the top of the pedestal, the rollers being held in their relative positions by a spider. The live ring is about 4 ft. diameter, and the table has a bearing upon it at four points, instead of at two points only, as in many tables. As an engine enters or leaves, the table rocks to take an end bearing on bolster plates, the use of trailing wheels being optional. The Greenleaf turntable has conical rollers concentrated in a cap bearing, no spider being used, and the table is steadied by vertical guide rollers on vertical axes, these rollers bearing against the base of the pedestal. The table tips and locks in line and surface for the engine to run on or off, unlocks when the engine is completely on or off the table, and then balances to a horizontal plane. Articles on turntable design were published in "Engineering News," New York, April 1 and 15, May 13 and Nov. 18, 1897; March 31, 1898.

A transfer table runs on a straight track at right angles to several parallel tracks, transferring engines and cars from one track to another. It is supported by several pairs of wheels running on rails spiked to ties or short blocks, the rails being usually 10 to 12 ft. apart. It may be operated by steam or electricity. A 70-ft. transfer table of 70 tons capacity on the Union Pacific Ry. has nine sets of 36-in. wheels with flat chilled treads. Each pair of wheels is carried between the ends of a pair of I-beams forming the transverse girders of the table, the bearings being on top of the

beams so as to keep the pit as shallow as possible. The nine wheels on one side are attached to a single shaft, made in sections, and this is driven by an electric motor of 15 to 25 HP., current being supplied by a trolley wire. The table has a travel of 300 ft. and will run at 90 ft. or 250 ft. per minute with full and light loads. The full power is not required for moving the table, but for hauling cars on and off the table by means of a capstan, the speed of the hauling attachment being 90 ft. per minute. The transfer table at the Oelwein shops of the Chicago Great Western Ry. has a travel of 750 ft., and will run at 200 ft. per minute with the heaviest engines, or 400 ft. with light loads. At the Burnside shops of the Illinois Central Ry. is a transfer table with pit 80 × 426 ft., having five tracks 17 ft. 7½ ins. c. to c. The depth from track rail to pit rail is only 13 ins. The walls are of concrete, 16 ins. thick, capped with yellow pine timbers 8 × 16 ins., laid flat and secured by anchor bolts. The table is operated by an electric motor, current being taken from an overhead wire.

Where many cars have to be turned, a Y track may be more expeditious than a turntable. The Peoria & Pekin Terminal Ry., which operates as the terminal of a number of railways at Peoria, Ill., uses a Y track for turning combination cars, sleeping cars, etc. It is situated about a mile from the yards, and a switch engine takes out 12 to 15 cars and turns them in 30 to 40 minutes.

Track Scales.

The pit for track scales should have walls of concrete, brick or stone, and a concrete floor graded and guttered for drainage. Walls of timber or dry rubble masonry are not to be recommended. The through track across the pit has its rails supported by stringers, so that cars running on this track do not bring the scale mechanism into action. The weighing track and the through or straight track are gauntleted, with a distance of about 10 or 12 ins. between the rails. The weighing track extends about a rail length on each side of the scale table and then another rail length connects it with the through track. The table is usually 30 to 42 ft. long, with a capacity of 60 to 100 tons. Those for weighing cars in motion may be 100 ft. long and of 150 tons capacity. They should be tested weekly, or at least monthly, by a test car. With the growth of the system of making up freight trains by actual loaded weight of cars, a greater number of track scales will be required, as noted in Chapter 12. Scales having the table suspended from overhead scale beams, instead of being supported by mechanism in the pit, are believed to be advantageous in many ways, and to have less wear on the knife edges, so that they are more durable and more reliable.

Bridge Tell-Tales or Ticklers.

Low overhead bridges are a constant source of danger to freight train brakemen, whose duties call them on top of the cars to set the hand brakes, although the general use of power brakes has greatly diminished the necessity for this work. Where low bridges are carried over the railway, men on the cars must be warned to stoop or lie down, as there is sometimes so little headway that unless a man lies flat on the roof or steps down between the cars he is very liable to be killed or injured. A tell-tale or "tickler" is usually placed for this purpose about 100 to 200 ft. on each side of the bridge

(or 50 to 100 ft. in yards.) The ordinary form consists of a gallows frame with single or double post, having a row of ropes or leather thongs, about 30 ins. long, hung from the cross-arm and reaching 3 to 6 ins. below the level of the lowest part of the bridge. When ropes get wet or frozen they will strike quite severe blows, and in this respect the leather thongs or straps are better, but, unfortunately, the brakemen have a propensity for cutting off the thongs for personal use. They also show their dexterity by catching the ropes or thongs and throwing them up as the train passes, so as to twist them around the cross-arm, and thus the brakeman on another train may be killed for lack of the warning. To prevent this, as well as to prevent the wind from blowing the ropes over the arm, the ropes or thongs may be attached to a bar suspended by links from the cross-arm, or each rope may be attached to the eye of a 1¼-in. rod, the upper end of the rod passing through the cross-arm and being secured by a nut; or by being bent over. This latter arrangement is shown in Fig. 130, which is the bridge alarm used on the Pennsylvania Lines at all bridges and structures less

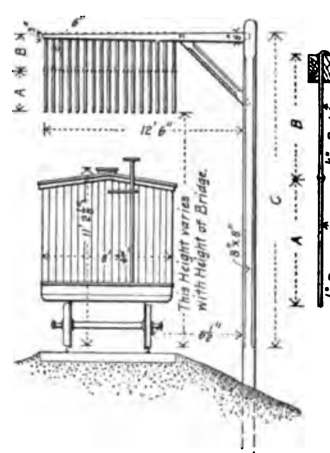


Fig. 130.—Bridge Tell-Tale; Pennsylvania Lines.

than 19 ft. 6 ins. clear above the top of the rail. The timber is of white pine, the post being tarred below the ground line. The bottom of the ropes must be at least as low as the lowest point of the bridge, and the requisite dimensions are as follows:

	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins.	ft. ins
Clear headway ...	15 6	16 0	16 6	17 0	17 6	18 0	18 6	19 0	19 6
Length of rope (A)	4 1	3 7	3 1	2 7	2 3	2 3	2 0	2 0	2 0
Length of rod (B).	3 5	2 11	2 8	2 5	2 2	1 11	1 11	1 11	1 11
Height fr'm r'l (C)	23 0	22 6	22 3	1 10	21 9	21 6	21 6	21 6	21 6

The Southern Pacific Ry. uses side frames built of old boiler tubes, each frame forming an inverted V with a spread of 8½ ft., the ends being set in concrete. These are 16 ft. apart for single track and 29½ ft. for double track, the posts being 8 ft. from center of track on curves and 9 ft. on tangents. To the cross-arm is attached a wire screen fringed with ropes, and on double track this arm is trussed. A similar arrangement is used by the

Cincinnati Southern Ry. Suspended from the cross-arm by three ½-in. eye-bolts is a wire screen, 8 ft × 2 ft. 8 ins., made of No. 10 wire, with 1-in. mesh and having a rim of ½-in.rod. From this are hung double braided ½-in. cotton ropes, well knotted to the screen and having the ends bound to prevent raveling. The ropes are 3 ft. 8 ins. long, 6 ins. apart, with the ends 17 ft. 10 ins. above the ties. Single and double post frames are used, with cross-arms 3 × 8 ins., and corner braces 3 × 6 ins. The clear width between the posts is 20 ft. Where there are several tracks to be guarded, as at yards, the ropes or thongs may be hung from a ⅞-in. wire cable, stretched across the tracks, but care must be taken to brace the posts well on the track side, and to provide means for taking up the slack of the rope, or the cable may sag so much as to strike a man and throw him from the train. The posts may extend above the point of attachment of the cable, and have suspension or stay cables from the top of the post to support the middle portion of the main cable.

A different type of tell-tale consists of a light pivoted horizontal rod about 1¼ ins. diameter, projecting across the track at proper height. The rod is pivoted so that when struck it swings easily round parallel to the track, a light suspended weight bringing it back to its original position. In the Walling tell-tale the rod is attached to a shaft inclined at an angle of 45° from the horizontal, and this shaft is carried by a swivel on the post so that it is free to swing at an angle of 45° from the vertical. When struck, the rod swings backward and upward, and the action of gravity returns it to and keeps it at its normal position. These rods, however, may strike a severe blow unless nicely balanced, and are liable to become frozen fast. They are inferior to the other type, and are comparatively little used.

Mail Cranes.

These are the fixed stands to which are hung the bags to be snatched off by the "catcher" on the passing mail car, and in 1893 there were about 8,700 post offices supplied with cranes and catchers. The cranes usually consist of a vertical post with two hinged horizontal arms, one above the other, to which are attached the top and bottom of the mail bag. These arms extend towards the track, and when not in use lie vertically against the post, so as to be out of the way. On four-track lines where the two middle tracks are the passenger tracks, the ordinary crane cannot be used. The Pennsylvania Ry. uses a crane with a long swinging arm to reach across the intervening track, but a better device is the iron crane used by the New York Central Ry., which is set between the tracks, and has the upper part turned parallel with the tracks when not in use. This is shown in Fig. 131, together with the gage for erecting it at its proper position in relation to the catcher on the mail car. The stand should be carried on the ends of two long ties, so that any alteration of level of the track by surfacing, heaving, etc., will not affect the relative position of the crane to the car.

Wooden mail cranes are generally used, and the standard form on the Louisville & Nashville Ry. is also shown in Fig. 131, being very similar to the form recommended by the Railway Mail Service Bureau of the Post Office Department. The arms are shown in position for the bag, but when it is taken off they swing to a vertical position, the upper one against the

back and the lower one against the front of the post. Small rubber blocks prevent jarring when the arms fall. The iron tongues over which pass the straps of the bags have no springs to hold the straps, a slight groove in the irons and the tension on the straps due to the arms, affording ample security. In the Post Office style of crane, the iron tongue is straight and flat, with a light spring of curved steel fitted to hold the straps. Sometimes the lower part of the post is enclosed in a box filled with stone, the steps

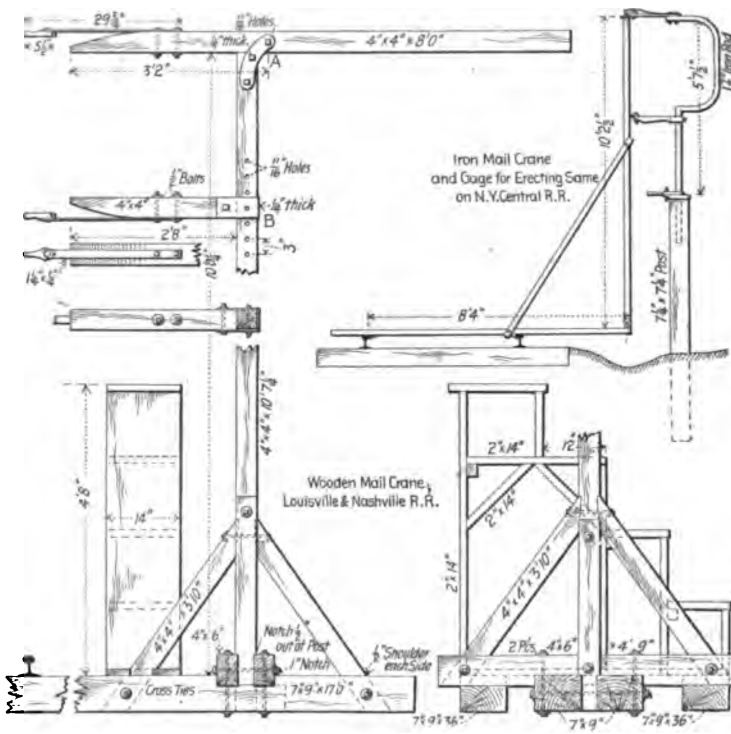


Fig. 131.—Mail Cranes.

forming a part of the box. The bill of material for the wooden crane shown in Fig. 131, is given in Table No. 14.

TABLE NO. 14.—BILL OF MATERIAL FOR MAIL CRANE.

	ins. ft.		ins. ft.
1 vertical post	4 × 4 × 11.0	2 cross ties	7 × 9 × 17
1 upper arm	4 × 4 × 8.0	2 blocking pieces	7 × 9 × 8
1 lower arm	4 × 4 × 2 9	2 step boards	2 × 14 × 12
4 braces	4 × 4 × 4.0	1 step board	2 × 12 × 7
2 cross pieces	4 × 6 × 4.9	1 step board	2 × 5 × 5
2 steel spring straps.		1 strap for lower arm (B).	
2 straps (curved) at top vertical post (A).		30 cast washers for 1½-in. bolts.	

8 bolts 1½ ins. diameter, through post and arms...... 5½ ins. under head.
2 " 1½ " " " post and braces...... 9½ " "
7 " 1½ " " " cross pieces.........13 " "
3 " 1½ " " " cross ties...........23 " "
1 movable pin for lower arm, ½ × 5 ins.

The present standard height of crane is objectionable in that it brings the upper arm (when carrying a bag) so high and so near the engine cab

window that enginemen are frequently struck when looking out of the window. It would be well if the height could be slightly reduced, the catching bar on the mail car door being correspondingly lowered. Mechanical devices to deliver and receive the bags automatically instead of being operated by the mail clerk on the car are in experimental use to some extent.

Bumping Posts.

At the ends of tracks in yards and stations, bumpers or bumping posts are generally erected to prevent cars from running off. In some yards it is considered preferable to leave the ends open, except near buildings, as it is cheaper to re-rail a car than to repair the end of a car which has struck the bumper heavily. In some cases, also, it has been found effective to replace the bumper by a flag, and to issue an order prescribing summary punishment for the first man who sends a car over the flag. In general, however, it is better to provide the posts and to rely on discipline to prevent the

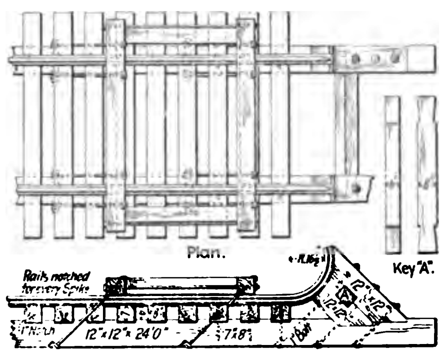


Fig. 132.—Low Bumping Post; Pennsylvania Lines.

rough usage of the cars. It is a poor plan to simply bend up the ends of the rails and place a heavy timber across them, as cars will easily jump the track and pull it endways, while there is liability of stripping the trucks and damaging the brake gear. One form of low bumper for yard use, which is not likely to be jumped, is shown in Fig. 132, and is used on the Pennsylvania Lines. High bumpers, however, which will catch the car frame or body of the car, are generally preferable. A bank of earth or cinders may be used in yards, being 2 to 3 ft. high, with a slope of 2 to 1, or it may have a vertical planked face backing a bumper post or frame. Concrete blocks are sometimes used for backing, as being more permanent, and less unsightly than earth banks.

The simplest form of high bumper consists of three heavy timbers: a sill, a vertical post, and an inclined back brace, all framed and strapped together, the sill being buried in the earth (parallel with the rails). A better form has two such frames, with one or more horizontal transverse timbers or deadwoods between them to take the blow of the car coupler or platform, and having inclined tie rods to the front ends of the sills. The bumper of

the Louisville & Nashville Ry., Fig. 133, is of this type, and is built of timbers 12 × 12 ins. The bottoms of the sills are 4 ft. below and the tops of the posts 5 ft. 8 ins. above the base of the rail. The deadwoods are faced by a $\frac{1}{4}$-in. iron plate 34 × 36 ins. With dressed faces and chamfered edges, the frame has a neat appearance for passenger stations, and the number of the track may be painted on the tops of the posts. The rails rest upon stringers supported by the cross timbers, bolted to the posts. An elaborated bumper of this same type is used at the ends of tracks on a slight down grade in the Cincinnati freight station, where there is a platform right behind the bumpers. This has sills 14 × 14 ins., 50 ft. long, 4 ft. apart in the clear, with five transoms 6 × 14 ins. (framed 1 in. into the sills at each end), and 1-in. transverse tie-rods. The posts are 14 × 14 ins., 7 ft. 8 ins. high from the sills, and placed 10 ft. from their rear ends. The back braces are 12 × 14 ins., and the inclined tie-rods are 2 ins. diameter, with special beveled cast-iron washers to avoid cutting the posts. The deadwood is 12 × 18 ins., and in front of it is a striking plate 8 × 8 ins., separated from it by six rubber blocks 6 ins. diameter and 5 ins. thick, with a 1-in. bolt through each. To the face of this latter timber are bolted two pieces 8 × 18 ins., 3 ft. 3 ins. and

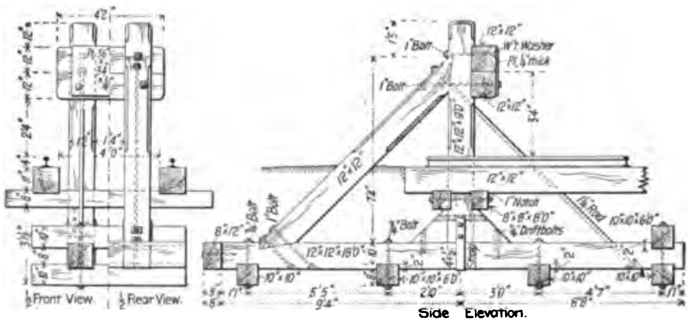


Fig. 133.—High Bumping Post; Louisville & Nashville Ry.

2 ft. 2 ins. long, the front one being faced with a $\frac{3}{4}$-in. iron plate 18 × 26 ins. The track ties are laid directly upon the sills, the alternate ties being secured by $\frac{7}{8}$-in. bolts. Many bumpers are fitted with rubber or coiled steel springs, but rubber is of little use, and the steel springs are almost invariably of insufficient capacity to take up any severe shock. Friction buffers, resembling the Westinghouse draft gear, have been suggested.

For terminal tracks in passenger stations, low bumpers are sometimes used, having double timbers with car springs set horizontally between them to take up the shock. It is more common, however, to use high bumpers of the type above described, but having the deadwood and striking timber separated by two or three pair of heavy car springs. Vertical stirrup irons are sometimes used to keep the springs from deflecting vertically, the upper end being bolted to the striking timber and the lower end embracing the rail head. A bottom timber may be provided to catch the car wheels when the frame strikes the upper one, and this may be a loose sliding timber, as the distance from wheel to end of car is variable. A sand track has

been used for this purpose, as already noted. Instead of braces and tie-rods, long A-frames made of old rails, attached to the sills and passing over the ends of the deadwood, may be used. The number of the track may be displayed on a target attached to the top of the bumper frame, for the information of trainmen and passengers. The hydraulic buffer stop designed by Mr. F. W. Webb and used by him on the London & Northwestern Ry. (England) is shown in Fig. 134. To the deadwood are attached two hydraulic cylinders, the piston rods of which have mushroom heads to fit the spring buffers on the end sills of the cars. The cylinder is 9 × 24 ins., with the front end open and the sides perforated with 30 holes ⅛-in. diameter, and is enclosed in another cylinder, leaving an annular space of 2½ ins. An air chamber maintains a pressure of 40 to 45 lbs. in the cylinder, and this is retained for some months with one charge. The cylinder is filled with a mixture of petroleum, soap and water, ensuring good lubrication. When a train strikes the buffers, the liquid is forced through the small holes and into the air chamber, the resistance increasing towards the end of the stroke as the number of holes for escape becomes less. The Ellis bumping post, which is largely used, has a single upright. Two T-rails secured to the ends of the track rails by six-bolt angle bars are bent upward and inward on an incline so that they meet at the back of the post, and are bolted

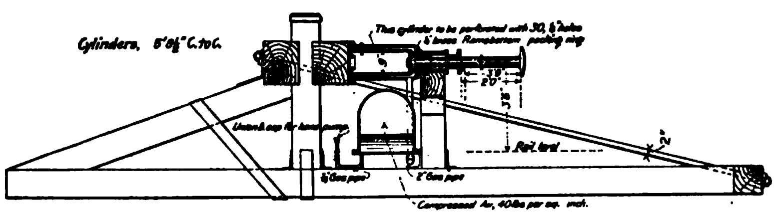


Fig. 134.—Hydraulic Buffer Stop; London & Northwestern Ry. (England).

to a heavy casting supported by an oak block or post just behind the main post. A rubber-cushioned striking plate is used for passenger car tracks, but rubber is liable to lose its elasticity and become hard. For bumpers on docks and wharves, the sill should be the same depth as the track stringers and the track in front of the bumpers should be well anchored down, while a back brace may be put in between the bumping timber and one of the dock piles or a special pile.

Terminals of elevated railways should be provided with specially strong bumpers to prevent cars in trains from falling into the street, but, as a rule, the bumpers are not very substantial. They are generally similar to those used on steam railways, the posts being braced by timbers at the back and tied in front by rods to the structure. A portable stop-block to skid the front wheels might well be used in front of the bumper, the principle of the device being the gradual absorption of the energy of the train, and all the space that can be spared should be given up to it. Beyond these devices, the track should incline sharply on an ascending grade, which rapidly grows steeper toward the end, thus absorbing the energy of the train. At the end should be a heavy timber bumper designed to take the shock of a collision and set perpendicular to the inclined track.

One form of the portable stop-blocks above referred to is shown in Fig. 135. It consists of a pressed steel or iron tongue (A), resting on the rail and connected by a loop or strap (B), at its rear end with a small double flanged wheel (C), journaled in the sides of the strap. Between the wheel and the back of the tongue is a wrought-iron brakeshoe (D), pivoted to the strap at (E), and resting on the rail and in a groove in the flat tread of the wheel. When a car wheel runs up on the tongue and strikes the block, this block is pressed hard against the wheel and rail, stopping the revolution of the car wheel, while the force of the blow carries the stop-block back along the rail until it comes gradually to rest, being held on the rail by the grooved wheel and by lugs on the tongue. A useful form of portable stop-block for use in locking cars on yard or shop tracks is shown in Fig. 136, and may be fitted with a padlock.

Spare Rails.

It is the custom to place one or more spare rails at the side of the track on every section or at every mile post, ready for use in case of emergency. They are generally carried on three stakes, 6 x 12 or 3 x 8 ins., 3 ft. to 4 ft. long, with the top cut like a step to form a seat for the rail base, or notched

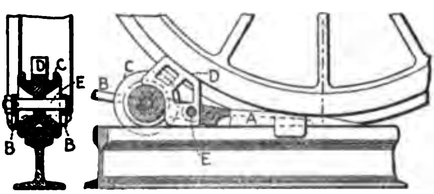


Fig. 135.—Rolling Stop Block.

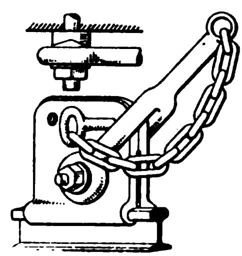


Fig. 136.—Portable Stop Block.

to hold the head and web of an inverted rail. They are placed at the side of or in front of the mile post, set 12 ft. apart, with the inner face 7 ft. from the rail and the top about 18 ins. above subgrade. If special attention is paid to neatness and finish, the ground may be dressed off level and covered with cinders and gravel for a length of about 33 ft. Where the spare rails are more than a mile apart, it may be desirable to keep two or more rails at each place, in which case the tops of the stakes can be offset to give two seats 4 or 5 ins. wide, or iron posts with brackets may be used.

Handcar Turnouts.

These are provided for convenience in taking handcars off the track and storing them while the men are at work. The Southern Pacific Ry. places them ⅓ mile apart, every third turnout being at a mile post, though this arrangement is varied where necessary. The roadbed is extended to 11 ft. from the rail for a width of 9 ft. and covered with 3 ins. of gravel to the level of the bottom of the ties.

Buildings.

Many of the smaller buildings have to be looked after more or less by the track department. These include section tool houses; cabins or shanties for switchmen, flagmen and gatemen; signal towers; small stations and flag stations; and dwelling houses for foremen and section men. Such buildings are usually of frame construction, and care should be taken that they are not allowed to get into a delapidated and unsightly condition. The roofs may be of shingles, tin, corrugated iron or tarred roofing felt; while corrugated iron may be used also for the covering or paneling of small station buildings and gatemen's cabins, and for the covering of freight sheds. The material and style of construction will depend largely upon local conditions, the climate and the amount of attention paid to appearance. Particulars of buildings of various styles are given in the book on "Buildings and Structures of American Railway," by Walter G. Berg. They should be at least 7½ ft. from center of main track or 7 ft. from center of sidetrack.

For painting frame buildings (of yellow pine) Mr. Samuel Wallis has recommended a priming coat as follows: 100 lbs. of pure white lead in oil, 4½ gallons of pure raw linseed oil, and 1 gallon of pure spirits of turpentine. This gives 8 gallons of paint ready for use, and should be allowed 48 to 60 hours for drying, or longer in damp weather. The second coat should never be applied until the priming is thoroughly dry. The second coat should be composed as follows: 100 lbs. of pure white lead tinted to shade with not more than 12 lbs. of tinting material, 5 gallons of raw linseed oil and 1 quart of good strong turpentine dryer. The third coat should consist of 5 gallons of pure kettle-boiled linseed oil to 100 lbs. of a paste composed of 60 lbs. of pure white lead, 30 lbs. of zinc white free from sulphides, and 10 to 12 lbs. of tinting material. Old and dry timber should be given a coat of pure linseed oil before being painted. For ironwork, the following is recommended: Priming coat; 100 lbs. of pure red lead to 5 gallons of pure linseed oil; second and third coats (for black color), 20 gallons of pure kettle-boiled linseed oil to 100 lbs. of a paste composed of 65 lbs. of finely hydrated sulphate of lime, 30 lbs. of fine quality lampblack, and 5 lbs. of red lead. This makes 30 gallons of paint. If much painting is to be done, it is well to have it made from good raw materials purchased by the company; but for repairs and small jobs ready made paints of good quality may be used to advantage.

As to the color of the buildings, various shades and combinations are affected by different roads. A plain dark tuscan red is a serviceable and well wearing color, and may be relieved by a darker amber brown on beltrails, posts, etc., if some attempt at a pleasing effect is permissible. Two shades of green also make a good combination, but the common dull yellow ochre with dull red trimmings (which is used by several roads) is extremely ugly. The tool house in Fig. 137 is painted in two shades of greyish brown, one being of a very light shade. One of the most attractive and cheerful styles is the colonial buff or yellow with white trimmings, adopted by the Chesapeake & Ohio Ry. A little light paint on mouldings, etc., will lighten up almost any style of coloring. Paint having an admixture of sand may be used at stations, etc., at about the height where loungers are in the habit of whittling the boards. It has a very discouraging effect upon the destructive amusement.

The painting and whitewashing of buildings, fences, cattle pens, etc., can be quickly, conveniently and economically done by compressed air. Several roads now have cars fitted up with air-brake pumps and reservoirs, the pumps being driven by steam from a locomotive, and a pressure of 40 lbs. being maintained in the reservoirs. Paint tanks are also mounted on the car. The painting nozzle consists of an iron tube with a flattened or funnel-shaped end, and to each nozzle are attached two lines of ½ or ¾-in. hose, one from the air reservoir, and the other from the paint tank. The flow of air induces a stream of paint or whitewash which is expelled in the form of spray, the flow being regulated by a valve on the nozzle. Paint must be mixed somewhat thinner than when it is to be applied with a brush. One gallon of paint has thus covered 150 sq. ft. of rough boarding,

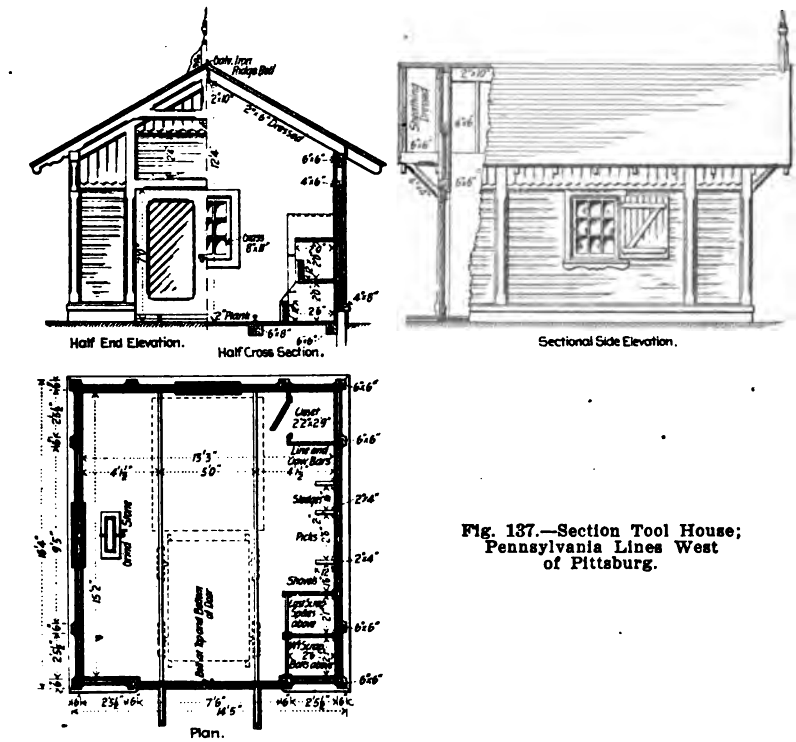


Fig. 137.—Section Tool House; Pennsylvania Lines West of Pittsburg.

and two men with nozzles can paint 5,000 sq. ft. per day. The advantages of this method of working are the rapidity of the work, the saving in cost of brushes where rough or unplaned lumber has to be painted, and the general reduction in cost, while paint thus applied readily finds its way to joints and narrow spaces almost inaccessible by a brush. On some large roads there is a regular traveling paint gang, which is carried from place to place on special cars fitted up with living accommodations and the necessary appliances.

Section Tool Houses.—These vary very much in size and design, but

should be large enough to hold the hand-car, tools, supplies, etc., and still leave room for the men to do such work as cutting shims, sharpening tools, sorting scrap, etc., in wet weather. The building is generally oblong in plan, and if very small it should be placed with its longer side towards the track, with the hand-car track laid through one end of that side, so as to leave the other end of the building unobstructed for the men to work in, but with buildings 14 or 15 ft. wide the track may be in the middle. There should always be room for the car to stand between the house and the track.

Shelves, hooks and racks for tools should be fitted up to suit the equipment. There should also be boxes for small tools and supplies; and boxes, kegs or half-barrels for different kinds of scrap. Long handled tools, bars, etc., may be stood on end, with the tops resting in inclined notches in a shelf. Edge tools should be placed where they are not liable to injury. There should be a locker or cupboard for special or expensive tools and supplies, and this may be placed in a room partitioned off and fitted with a

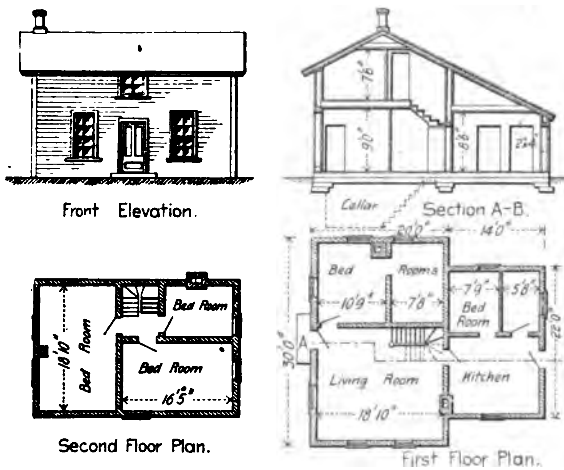


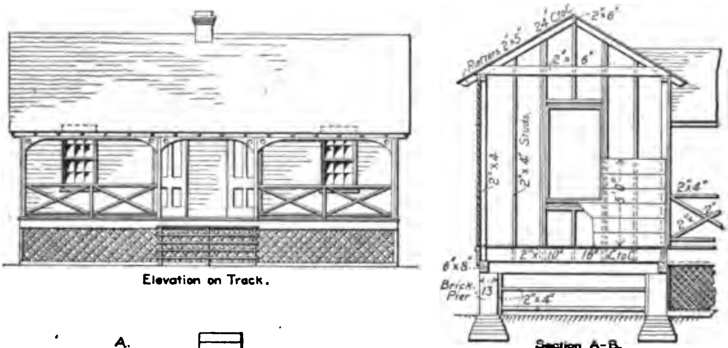
Fig. 138.—Section House; Canadian Pacific Ry.

desk for the use of the foreman in writing up his reports, time books, requisitions, etc. A sliding door, carried on an overhead rail, like a freight car door, is generally preferable to double swing doors, as being more easily handled in stormy weather, and less likely to get out of order or to be damaged by being swung to and fro.

The standard tool house of the Lehigh Valley Ry. is 16 x 20 ft. inside; and has the narrower gable end toward the track, with a wide sliding door for the hand-car at one side, and a smaller door for the men at the other side of the same end. As the sliding door fouls the smaller swing door when open, it would probably be better if the smaller door were placed in the side of the house. The building has a foreman's room, 6 x 8 ft., in one corner; and at the rear end of the house are a fireplace and workbench. A neat and convenient design is that of the Pennsylvania Lines West of Pittsburg, Fig. 137. It is 15 ft. 2 ins. long, and 13 ft. 3 ins. wide in the clear inside, and has the hand-car track in the middle, with room for the hand-car

and push-car, as shown by the dotted lines. Double swing doors are used, but there is said to be no trouble in handling them. The general construction and arrangement are clearly shown. The building is painted in two shades of light grey, and the average cost is about $175.

Section Houses.—In order to have the trackmen live on their sections it is often necessary to provide houses for them, the foremen very generally



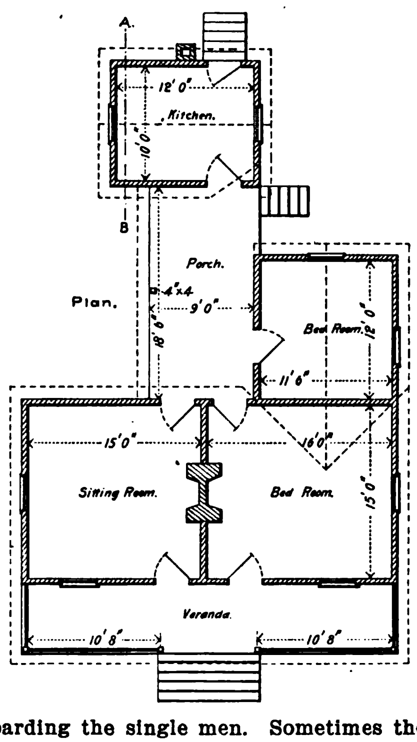


Fig. 139.—Section House; Louisville & Nashville Ry.

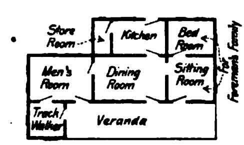


Fig. 141.—Plan for Section House.

boarding the single men. Sometimes these buildings are very cheap and unnecessarily bare in appearance, but they may be made quite attractive with very little expenditure. Fig. 138 shows a very plain house of the Canadian Pacific Ry. In "Engineering News," (New York), of May 26, 1892, were shown some simple but neat and inexpensive little houses built for

the negro section hands on the Macon & Birmingham Ry. The cost of these was only about $200, and to avoid monotony three or four standard designs were used. Boarding houses should be well built, roomy and convenient. They should be made comfortable and kept neat, and these requirements are specially important for buildings far from a town, as good men will not stay in unpleasant quarters. Sometimes the house is furnished to the foreman, free of rent, the foreman undertaking to keep it in good condition and repair. On some roads a prize is awarded annually for the best kept section house and grounds. A simple and convenient plan is shown in Fig. 139, which is the standard section house of the Southern Division of the Louisville & Nashville Ry., and Fig. 140 shows the section

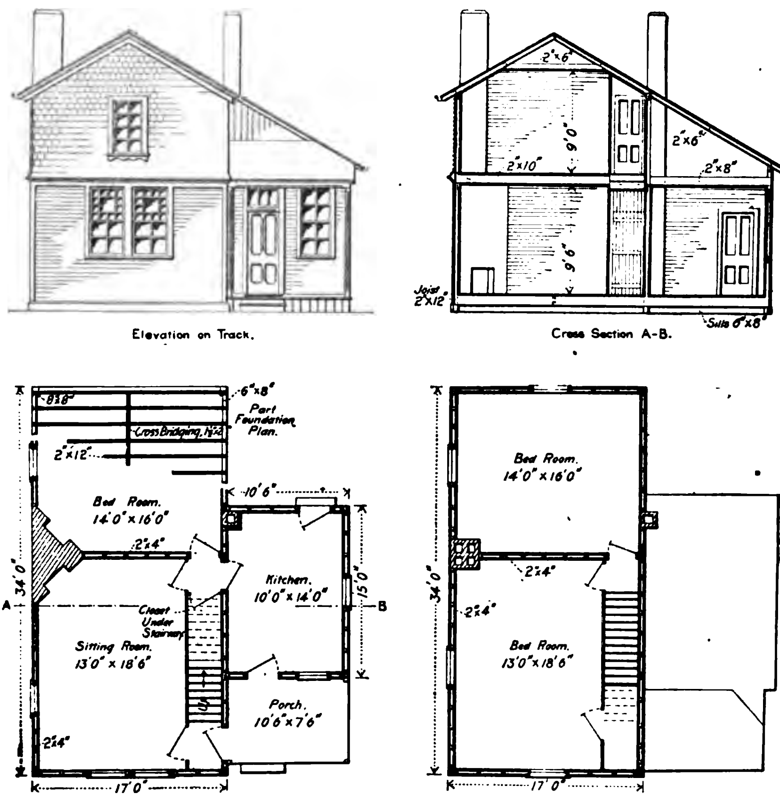


Fig. 140.—Section Foreman's House; Louisville & Nashville Ry.

foreman's house of the same railway. A sketch plan of a dwelling house for section men is shown in Fig. 141.

Telegraph and Signal Tower.—A neat design of tower for telegraph operators, signalmen, etc., is that of the Chesapeake & Ohio Ry., shown in Fig. 142. It has two rooms, the lower one square and the upper one octagonal. The platform sills, joists and floor are of oak, while the timbers of the tower are of heart pine.

Watchman's Cabin.—The cabin for watchmen, gatemen or switchmen may be square or octagonal, the latter giving the better view, and if two adjacent sides are extended to meet at right angles, the extra space will afford convenient room for a long bench or a berth. The cabin should be not less than 6 ft. square or diameter, 7 ft. high inside, and fitted with a locker, chair and stove. There may be a shelter over the sidewalk where

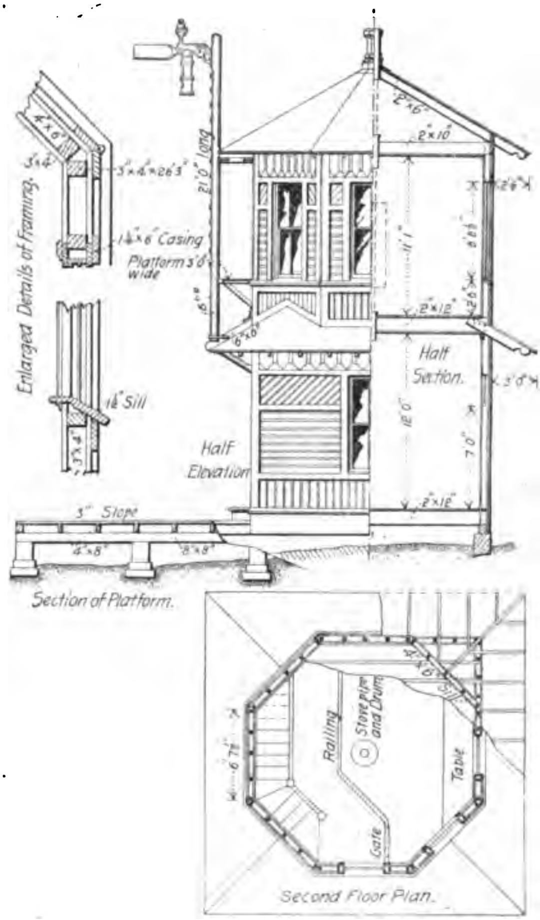


Fig. 142.—Telegraph Tower; Chesapeake & Ohio Ry.

the man stands when operating the gates. For suburban crossings, where appearance of the cabins is to be considered, very neat and tasteful designs can be built at small expense. The comfort of the men should be carefully looked to, an inner lining and ceiling or a layer of felt or tarred paper being used where the winters are severe. Similar cabins may be used for watchmen, yardmen, car inspectors, weighing machine men, etc. In yards, and where the railway runs through the streets, it is sometimes nec-

essary to place narrow cabins between the tracks or between the track and the roadway. These may be about 3 ft. 8 ins. × 8 ft. 3 ins., but should never be placed between tracks which are less than 15 ft. 6 ins. c. to c.

Station Platforms.

Railway station platforms are, in this country, usually level with or only a few inches above the level of the rail heads, except for elevated and some suburban railways, where the platforms are level with the car floors (on the English system), as in Fig. 93. The platform should in general be 3 to 6 ins. above the rails, and within easy reach of the lowest steps of the cars. The edge should be 24 or 33 ins. from the rail, or 5 ft. 6 ins. from center of track. The main part of the platform should not be less than 10 ft. or 12 ft. wide, but at small stations the portions beyond the station building may be reduced to 6 ft. in width. The platform should be level with the floor of the station building, and incline slightly towards the track, while the ends should have an incline of 1 in 10 to the ground level. Where there is much passing across the tracks (though this should be avoided wherever possible), planking may be laid between the rails and between the tracks, being flush with the tops of the rails, and leaving the necessary flangeway. Freight platforms should be level with the floors of the cars, being about 3 ft. 8 ins. or 4 ft. above the rail, and having the edge at least 3½ ft. from the rail, this clearance limit varying on different roads. A platform about 3 ft. 3 ins. high should also be provided for loading freight from or upon wagons and carts, an inclined approach being built in each case. In some cases the passenger platform is carried along in front of the high freight platform, each being 6 ft. wide, and the edge of the latter being about 8 ft. from the rail, but this is awkward for handling freight, as bridging planks have to be thrown across the car. It is better to extend the freight platform to the clearance limits, and the passenger and freight platforms should be connected by an easy incline for baggage trucks, etc.

For terminal and important stations (freight and passenger), concrete, asphalt or flag paving is very generally used, and the former is an excellent material, providing that it is of such quality that the surface will not readily become slippery. A cheap cinder concrete may also be used for ordinary platforms, having a curb of brick or wood. Where brick paving is used, it is generally uneven and noisy, owing to poor foundation and the use of ordinary cheap building brick. Good paving brick on concrete should stand well, and special hard paving bricks, 9 ½ × 4¼ × 4 ins. have been used, being laid on 2 ins. of sand or 6 ins. of gravel, tamped to surface, and the joints properly grouted. Wood, however, is the usual material for platforms, and where the surface is to be level with the rails, it may have pine planks 3 × 6 or 2 × 4 ins., nailed to oak sills 4 × 6 ins., laid at right angles to the rails and 24 to 30 ins. apart. The timber, however, is liable to be damp and to rot, even if laid on sand, gravel or cinders, and under such conditions it will gradually develop holes which are likely to trip persons walking on the platform. It is much better to support the sills on small concrete or masonry piers, excavating the ground so as to leave an air space under the platform, as in Fig. 142. For a platform 18 ft. wide, the sills may be 8 × 8 ins. or 6 × 10 ins., 18 ft. long, with the ends and middle supported by brick piers 12 × 12 or 16 × 24 ins., about 3 ft. deep, and 8 to 12 ft. apart, c. to c.,

longitudinally. Oak posts or pile ends may be used instead of the piers. The sills slope 2 ins. towards the track. Upon the sills are joists or floor beams about 3 x 10 ins., 12 to 16 ins. c. to c., laid parallel with the track and braced by bridging pieces. To these beams are spiked 2-in. floor planks. A layer of ashes or gravel should be placed under the platform, with its surface at least 6 ins. below the sills, so as to prevent the growth of weeds. For the ends of small platforms extending beyond the station buildings, an economical plan is to lay two lines of timbers 8 x 16 ins., connected at intervals of 10 ft. by transoms 6 x 12 ins., and ⅞-in. tie-rods, between which is a filling of gravel or cinders. (See also Chapter 2.)

Floors for Roundhouses and Shops.

For roundhouses, etc., brick is probably the best paving material, as it will stand heavy trucking, and is easily drained and kept clean. Hard-burned vitrified brick should be used, laid on edge on concrete or 2 ins. of sand or 6 to 12 ins. of slag or gravel, tamped level and grouted with hot tar. The rails may rest on timbers 12 x 14 ins. on the pit walls, with a plank between the outside of the rail and the paving. A wooden floor having planking spiked to sills (of old cars or ties) embedded in cinders is rarely kept in good repair, but is better than a floor of loose gravel, the dust of which is blown over the engines. A floor of wooden blocks sawed from old ties and laid on plank or rolled gravel would be better.

For tracks in shops, the rails may be laid on longitudinal timbers or cross ties (with wooden or iron cross ties under the former) embedded in or laid upon concrete; a tie-plate being placed under the rail ends at each joint. They may also be laid directly upon the concrete, being held by clamps and nuts on 12-in. bolts bedded in the concrete and having anchor plates on the lower heads. A groove or channel about 6 or 8 ins. wide should be left for each rail, to be filled in after with concrete, so that in renewing rails, etc., the concrete of the main floor will not be broken. A floor of this kind may be made as follows: 12 ins. of gravel, tamped and leveled; 3½ to 4½ ins. of concrete (2 to 4 sand, 4 fine gravel and 1 cement); 2 ins. of cement (5 sand to 1 cement), and a ½-in. finishing coat of equal parts of sand and Portland cement, or 1½ ins. of sand and cement 2 to 1. The new shops of the Philadelphia & Reading Ry. have floors of bituminous concrete (cement concrete at pits) composed of 1 gallon of coke-oven composition to 1 cu. ft. of screened cinder, laid hot and well rammed. In this are embedded yellow pine sleepers, 6 x 6 ins., 4 to 5 ft. apart, on which is an under floor of hemlock planks, 3 x 8 ins., with a wearing floor of maple boards, 1⅛ x 4 ins., laid at right angles to the hemlock. Tracks are laid on pine ties 6 x 8 ins., 8½ ft. long, embedded in the concrete with their tops 5 ins. below the floor surface. The wooden floor is more comfortable for the men in winter.

A tar concrete floor may be made of a layer of clean, fine gravel and sand, well mixed with pitch and tar (1 part pitch to 2 tar), the layer being 1 to 2 ins. thick and laid on a 6-in. bed of gravel or of broken stone mixed with gravel to fill the voids. Plank floors laid directly upon cement concrete are subject to rapid decay, as the cement is hygroscopic and contains water in the pores, and is a good conductor of heat. Asphaltic concrete is a poor conductor of heat; it is antiseptic in its properties, and wood floors placed

upon it have proved very durable, though the pungent smell of the tar lasts a long while, and may be objectionable in storehouses where certain goods are stored. The use of tar concrete is not advisable where heating pipes come near it, and in cement concrete fine crushed granite, in place of sand, will give a more durable and better looking surface. The bottom planking should be well seasoned, and painted with some preservative, otherwise dry-rot may set in where any considerable area is covered by machines.

CHAPTER 12.—SIDINGS, YARDS AND TERMINALS.

Sidetracks may be considered as being divided into two classes: (1) Those used in train service; (2) Those used for trains and cars entering and standing in yards and at stations. The former are now very generally called by the English term "sidings," to distinguish them from tracks of the second class. The track of the latter is generally of inferior construction, having light and worn rails, few and old ties and a partial equipment or spikes and bolts. This may be permissible to a certain extent, but the track should be in good and safe condition for its service, and should not be left neglected with rotten ties, battered rails, loose bolts and spikes, etc. A sidetrack in such condition, with bad line and surface, is generally an indication of carelessness or neglect in the maintenance department. Freight sidetracks at small stations may be placed to suit local requirements, the freight house track being (1) at the back of the building, (2) between the main track and station, or (3) between the main track and a freight shed on the opposite side from the passenger station. The side track may be slightly lower than the main track, so that cars will not foul the main track. All turnouts should be well laid and ballasted, and kept up to the standard of the main track, while passing sidings should be maintained as part of the main track. Turnouts from main track to sidings or sidetracks should be protected by safety devices, as noted in Chapter 7.

Sidings.

These are provided to enable trains to pass on single track roads, and to relieve traffic on double track. In the latter case, they allow freight or inferior trains to keep out of the way of faster superior trains and at the same time to continue their own course on the relief track or siding. Passing and main tracks should be at least 13 ft. c. to c.

Arrangements for "lap" passing sidings are shown in Fig. 143, the first four being used on the Pittsburg, Fort Wayne & Chicago Ry., to suit local conditions. Plan No. 1 is a middle siding with the pulling-out switches at the tower. Westbound trains take the siding at (A) and pull out at (B); while westbound trains take the siding at (D) and pull out at (E). Each of the two sidings will hold four trains, which requires 4,300 ft. of track on the Eastern Division. The sidings are connected and have the end switches (C) and (F), so that in case of emergency the entire length of track can be used for trains in one direction. The telegraph tower is located at the center, or "lap," the switches (B) and (E) being operated from the tower

This relieves the trainmen from responsibility for the switch when they have a clear signal to go on, and prevents them from pulling out onto the main track without the knowledge of the operator. Plan No. 2 is a middle siding in which trains pull in at the tower. Westbound trains enter at (B) and pull out at (C); while eastbound trains enter at (E) and pull out at (F). This plan is not used as much as the former. As the entering switches (B) and (E) are operated from the tower, trains do not have to stop before taking the siding. In order to control the outgoing movements and place the siding entirely under the control of the operator, an electric starting signal may be placed at the pulling out switches (C) and (F). This is operated from the tower and interlocked with the switch, so that a train cannot pull out without the knowledge of the operator.

Plans Nos (3) and (4) are outside lap sidings, the operation of which is similar to that of Nos. 2 and 1, respectively. These outside sidings are used on long, straight lines to avoid the necessity of putting the reversions in main track which the construction of a middle siding would require. The capacity of the siding for trains in one direction cannot, however, be temporarily increased, as with middle sidings, except by crossing over and interfering with through traffic in the other direction. On the Eastern Division, the lap sidings are placed at intervals of ten miles, the intention being to build additional sidings between them as the traffic may demand. By having sidings with a capacity for four trains, at intervals of five miles, with switches operated from a tower so that trains need not stop, a maximum facility of train movement is obtained. When the traffic becomes too heavy for such a movement an additional main track or tracks will be required. On the Pennsylvania Ry., the arrangement shown in Plan No. 5 is used where the sidings hold only one or two freight trains, and also where it is desired to maintain only one telegraph office. Where the third tracks are of such length as to lap over two block sections and get the use of these telegraph towers, the connections are made as shown in Plan No. 6. A similar arrangement to Plans No. 3 or No. 4 can be applied to single track, as shown in Plan No. 7, and this greatly facilitate the handling of heavy traffic With such an arrangement, two trains, headed in opposite directions and waiting upon the sidings, may proceed upon their respective ways immediately after the passage of the train on the main track, without waiting upon each other's movements. These sidings may be long enough to accommodate two or more freight trains, each of which pulls out as it gets the signal from the tower, the other following up to the tower. Thus trains in opposite directions do not interfere with one another, and no time is lost in waiting for train orders from a tower at a distance. The switches may be operated from the tower, the signalman being notified of the train orders. These sidings may be eventually extended to form a double track.

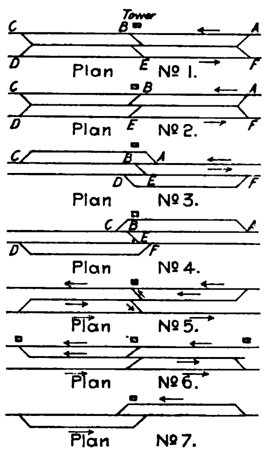


Fig. 143.—Plans of Lap Passing Sidings.

On double track roads, relief sidings are often used, placed between or outside the main tracks, as already shown, and these are sometimes long enough to be used as a running track. If they are short, they may have a switch at one end only, thus avoiding facing switches, and obliging trains to back into the sidings. When a middle relief track connects with the crossover connecting the two main tracks, the movement of trains from the relief track may be governed by the dwarf signal at the crossover switch. In order to allow of a second train being got clear of the main track when the relief track is occupied, the train may be switched onto the opposite main track, a call bell connected with the block signal tower and interlocked with the dwarf signal being used to control the heading out of this train. Similarly, where a train takes an outlying sidetrack on a block section, and the block is thus clear and yet has a train on it, the towerman is notified and gives a following main track train the green or "caution" signal. In such cases, a bell circuit connects the outlying sidetrack with the tower, by which the conductor can notify the signalman when his train is clear of the main track, and when the superior train has passed the switch.

Yards and Terminals.

The word "terminal" is properly applied to cover all the property and facilities provided for the conduct of business at the end of the line, or at the end of a division or a district. The terminals may be subdivided into passenger and freight terminals, and further classified as line terminals, division terminals, branch or district terminals, etc. The word "yard" is properly applied to the system of tracks, independent of running tracks, which is provided at terminals and division points, intermediate points, stations, etc., for storing and switching cars in the work of making up, distributing and inspecting trains. The cost of yards and of yard operation is an important item in the total cost of transportation and general operation, and among the improvements which have a bearing upon the reduction in these latter costs is the designing of yards and terminals with two special objects in view: (1) To increase the speed and facility of handling the cars in the necessary switching movements; (2) to increase the facility of handling freight in loading and unloading cars. Freight handled in bulk between fixed terminals, as in the case of coal and ore, requires comparatively little switching and inexpensive terminals. General freight, however, has to undergo a complicated series of movements (aggregating a considerable mileage) in extensive yards which often occupy highly expensive land. The cost of terminal work, therefore, is an important item in the total cost of freight service. These matters were discussed by the writer in a paper on "Railway Yards and Terminals," read before the Western Railway Club in November, 1900.

As to passenger terminals and yards, very little can be said in the way of laying down general rules, the conditions and requirements varying so greatly in each case. Convenience of operation is usually of greater importance than economy of yard service, as the switching movements of passenger cars are comparatively limited. At terminal stations, the tracks are generally arranged in pairs, with platforms between, but in the Southern terminal station at Boston, which represents the latest practice and was designed with a

free hand, the two tracks of each alternate pair are separated by a platform 8 ft. wide, used exclusively for baggage. These tracks are 17 ft. c. to c., while the passenger platforms are 14 ft. wide, the adjacent tracks being 23 ft. c. to c. In the Grand Central station, New York, the platforms are only 8 ft. and 10 ft. wide, 21 ft. 6 ins. apart in the clear, with tracks 11 ft. 6 ins. and 12 ft. c. to c. The new station of the New York Central Ry. at Albany has tracks in pairs between platforms 20 ft. wide and 20 ft. apart, with two rows of columns (for umbrella roofs) on each platform, 5 ft. from the edge. In the new Pittsburg station of the Pennsylvania Ry. the pairs of stub tracks are 17 ft. between outer rails, and 20 ft. between the inner rails of adjacent pairs. Platforms between tracks should have a minimum width of 12 ft., and 18 to 20 ft. is a better width, especially if there are columns or if baggage is conveyed on the platforms. The main platform between a sidehouse station and the tracks (parallel with the latter) should be 20 to 30 ft. wide; while the transverse platform between the headhouse and end of tracks in a terminal station should be 30 to 75 ft. wide. At many large stations there must be stub tracks for trains making these their terminal points, and also through tracks. Stub tracks should be in pairs, and connected at their ends by a crossover or transfer table, so that the engine of an incoming train can be sent to the roundhouse, coaling station, etc., without the necessity of waiting for its train. Ample connection should be made between the station or house tracks and the main tracks, with interconnections by slip switches, etc., so that there will be no liability of a station track being blocked. At the Boston station, above mentioned, two intersecting double track lines form an X in the middle of the yard, and cross all the approach tracks. At each intersection is a double slip switch, thus giving an almost illimitable variety of combinations for connecting any of the 28 station tracks with any of the approach tracks. The special equipment for passenger yards will include express, baggage and mail car tracks, car cleaning tracks, inspection and repair tracks, engine and car storage tracks, turntables, coal and water supply for the engines, water supply and ice for car tanks, etc. Passenger terminals were discussed in Engineering News Jan. 12 and June 1, 1899.

For freight yards and terminals, the facilities must include provision for sorting and distributing cars in making up outbound trains or breaking up inbound trains, as well as tracks for cars which are to be loaded, unloaded, repaired or stored. They must have provision for changing engines and cabooses, inspecting and repairing cars, cleaning and housing engines, supplying coal and water to the engines, ice to the refrigerator cars, and water to the stock cars. Cattle pens, spur tracks to factories, docks, elevators, etc., and other special equipment, may also be required for special classes of traffic. There must be ample crane equipment for handling freight, particularly very heavy articles. Where engines merely lay over for a short time, and then make a return trip, a convenient plan is to put in a turntable and radial tracks for these engines. At division points, through freight trains will require little attention beyond the changing of engine and caboose and the general inspection of the train. Incoming local trains, however, must have the through cars sorted out and the terminal cars switched to unloading tracks, while the outbound trains must be made up with cars in proper order for delivery consecutively at the several stations

on the run. At small stations only a few tracks are required for switching, loading and unloading cars, and these do not form a "yard" unless they include at least three parallel tracks arranged to be operated in series for the switching and storage of cars. A terminal yard is subdivided into separate groups of tracks, termed "yards"; such as receiving yards, distributing yards, classification yards, advance yards, eastbound and westbound yards, etc., all interconnected.

limit of yard [illegible]

The switching movements are sometimes made entirely by switch engines coupled directly to each car or cut of cars to be moved, but this plan is not adapted for large yards. In a poling yard, the distribution of cars is effected by an engine running on a track parallel with a "drill" track and pushing cars onto the "ladder" track by means of a swinging pole attached to the engine or a special poling car. In a gravity yard, the distribution is effected by sending cars down grade on the drill track to the ladder track. Both of these methods are often used in combination. Poling is the method most commonly used, often assisted to some extent by gravity, but this latter method is not employed so comprehensively in this country as abroad. In Europe, some yards are operated almost entirely by gravity, the cars passing in this way from one set of classification tracks (or "gridiron") to another. In this country, however, the gravity system is usually confined to a few tracks for certain movements. A grade of 0.5% is very generally used where the gravity system is merely auxiliary to poling, but where cars are switched by gravity alone a steeper grade is used, from 1 to 1.25%. A "lead" track connects either end of the yard with the main track. The "body" tracks are the parallel tracks (in groups) upon which cars are switched or stored, and these are connected with or open from a diagonal "ladder" track. One of the body tracks of each group is kept open, or clear of cars, to allow of through movements from one group to another. A "drill" track connects with the ladder track (being generally parallel with but beyond the body tracks). In poling yards, the cars are fed from the receiving track to the drill track by switch engines, and each car or cut of cars is pushed forward by the poling engine on the parallel poling track, giving it sufficient impetus to run down the ladder track and through the switch of the body track for which it is intended. The poling track should extend as close as possible to the ladder track, and may even be continued parallel with it, so that heavy cars or those which fail to reach their proper switches may readily be handled. Car storage tracks should be double ended, or else there is a tendency of old cars to remain neglected at the dead end. They should also be so connected with the classification tracks that in making up trains the cars can be taken from the classification or storage tracks, as required.

The tracks should be developed from one or two principal side tracks, so that the only switch in the main track will be that of the lead track. Where 20% of the trains are of maximum length, the receiving tracks should be long enough to take these trains, but otherwise they may be long enough merely for the average train. They should be of sufficient capacity to avoid blocking the main track by holding a second train until the first one is inspected, marked and distributed. The length of track should be the same in all the groups, and if the length is too great it will necessitate switching the cars at high speed, making it dangerous for the men to jump

on and off, and inducing a liability of injury to cars by colliding with each other. The aggregate length of the yard will also be excessive, causing considerable trouble in the movements of the switchmen and yardmen. The separate "yards" or tracks, which make up the terminal yard as a whole, must be so arranged in series that the cars will move steadily forward in the several switching movements, as all backward or reverse movements detract from the highest efficiency of working. The entire yard terminal will be in two parts, for traffic in opposite directions, and each part will have separate groups of tracks for classifying, sorting, etc., as shown in Fig. 144. It should be located on a tangent if possible, and the main track may pass through or around it, provision being made for a route around or through the yard, respectively, in case of any block on the main track.

The body tracks should be not less than 13 ft. c. to c., while the car repair tracks should be 20 ft. c. to c. The first yard track may be 16 or 20 ft. from the main track (c. to c.) to allow room for water columns, etc. Tracks for cars to be unloaded by teams may be 25 to 30 ft. apart, to allow of the passage of wagons and teams between the cars. The space between these tracks should be macadamized or paved with brick or stone if there is much heavy trucking. It should at least be well coated with cinders or gravel, to prevent mud and enable the wagons to be hauled easily. The 15th St. yard (New York) of the New Jersey Central Ry. has the team tracks in pairs, 360 ft. long, 12 ft. c. to c., with stone driveways 35 ft. wide (rail to rail) between the pairs of tracks. These tracks are at an angle of about 45° with the ladder track and have turnout curves of 39°. The terminal yard of the Harlem Transfer Co., New York, has circular tracks around an annular oval freight house 188 x 158 ft., 35 ft. wide, the wagon court being on the inside. This gives a great amount of house track, with facility in operating. The curves are of 90 and 104 ft. radius, the outer rails being elevated 2 ins., and the gage widened ½-in. The surface of the roadway is generally 12 ins. above the ties, with a curb at the sides, or having the paving crowned.

The freight yards are a very defective part of the railway system as a whole, one reason for this being that the great expense involved in switching and handling cars in yards has only been recognized by operating officers within recent years. While there are many yards which are well laid out for economical operation, yet very often the general design and detailed arrangement have been made more or less at haphazard. Many yards of importance have developed gradually from smaller yards, and tracks have been lengthened, new switches and tracks put in here and there, and alterations made from time to time as immediate requirements seemed to demand, without regard to any general plan. Such a yard becomes eventually a mere patchwork of tracks and switches, the operation of which involves much unnecessary work and delay in handling the traffic, with heavy maintenance work. In large yards, the traffic is usually so great that entire reconstruction is practically impossible, but a good and comprehensive design should be planned and gradually introduced. In staking out tracks in a large yard, stakes of different colors for different tracks may conveniently be used to avoid confusion, and the stakes at mouth of

switch and point of frog may be marked "M. S." and "P. F." (See also Chapter 22).

Defects in yard design are very frequently due to a lack of co-operation between the constructing and operating officers. In some cases a yard is enlarged or extended without the assistance of the engineer, and the result is an awkward arrangement of curves and switches which increases the difficulty of handling cars and increases the wear on wheels and rails. In other cases a freight yard has been planned without inquiring into the local conditions and the traffic requirements, with the result that the yard, while appearing very convenient on paper, is a source of much trouble to the operating department. Thus the switches may be badly located, or the track scales, repair tracks, or other special points may be inconveniently arranged or so located that they can only be reached by crossing or fouling other tracks which are in constant use. Most railway engineers give too little study to the operating side of railway service, and in consequence do not realize the importance of many smaller items and details in economizing work, or realize their relation to the general operating expenses of the railway. For these and other reasons it is imperative, in the interests of efficient service, that the officers of the constructing and operating departments should consult together as to the best arrangement for any one yard, while information should be sought from the yardmaster or other local officer as to any special or local service to be provided for, or any special difficulties resulting from the existing arrangement.

The main idea in enlarging a yard is usually to provide more tracks for cars to stand on, the too general idea of a yard being that the principal consideration is to have plenty of tracks upon which to store cars, while as a matter of fact a yard is intended for sorting and distributing cars, rather than for storing them. The quicker the car is passed through the yard from the time of its arrival off the road until it is delivered at its unloading track or sent out again to continue its journey, the greater will be the operating efficiency and economy of the yard service. This economy and efficiency will also extend through the whole freight service, for if the cars are handled promptly there will be less delay in providing empty cars as called for, and consequently the capacity of the equipment will be increased, thus avoiding the necessity of purchasing new cars. If a yard is too large, or its track capacity too great, there is likely to be a lack of promptness in clearing it and getting the cars moving over the road. On the other hand, if it is too small, blockades will almost certainly occur, interfering with the movement of freight trains on the road, while the hurried and complicated switching in an overcrowded yard will tend to greatly increase the damage to rolling stock. In all yards there is more or less of a tendency to rough handling of cars, which can be kept in check only by strict enforcement of discipline, and a full enquiry as to the cause of and responsibility for each case of damage.

One important defect resulting from the general failure to recognize the important relation of yard service to the general operation of a railway system is the common failure to provide proper equipment. Not only are the yard tracks very often of light and poor construction, but their maintenance is more or less neglected, and low joints, missing bolts, loose spikes, worn ties, and switches and frogs in various grades of bad repair are common

conditions to be met with in the average yard. The sectionmen in charge of the yard, finding it impossible to keep all these tracks in proper condition under the traffic which they sustain, naturally become more or less careless and discouraged. The condition of the switching engines is frequently on a par with that of the track, the tires being worn hollow to an extent which is most destructive to the track, while the valves are badly set, and all the connections are more or less loose. It is not in the nature of the average engineman to give his best endeavors to the proper handling of such a "mill," so that the amount of damage to cars in switching will probably bear some relation to the amount of maintenance expenses for tracks and engines.

The use of heavy rails, or even of good rails, in yards, is very generally assumed to be unnecessary and uneconomical in view of the severity of the service and wear, and this is one reason for the dilapidated yard tracks which are so common. The fact that good heavy rails will reduce the wear of both tires and rails in yards as well as on the open road, and that the expenses of maintenance of track and equipment will be correspondingly reduced, have probably never occurred to many officials, and they have felt that it would be waste of money and material to put such rails in their yards. The New York Central Ry. has introduced its 100-lb. rails in the passenger yards of the Grand Central terminal station, New York city, and has obtained a decided economy in track work, in conjunction with other advantages. The yard has about 7.86 miles of track in all: 2.3 miles with 100-lb. rails, 1.2 miles with 80-lb., and 4.36 miles with 60-lb. rails. There are 23 double slip switches, 1 single slip switch, 65 single turnouts, 4 crossovers, and 2 crossings with rigid frogs. The tracks now laid with the 100-lb. rails include those carrying the heaviest traffic between the station tracks and the four-track main line approach, and they are equipped with split-switches, slip-switches, turnout frogs and crossing frogs, all of the 100-lb. rails. The yard is controlled entirely by interlocking plant, and the lever men in the main tower at first objected to the heavy switch rails, claiming that it would be very hard work to throw them. As a matter of fact, these switches are found to work even more easily than those with lighter rails, as the latter become bent vertically, causing them to bind on the slide plates, whereas the former are stiff enough to hold their shape. The yard maintenance force includes 3 track foremen, 3 track men and 30 laborers; for maintenance of the interlocking plant there is a foreman with 6 repair men.

Split switches should be used, of a uniform pattern, and the frogs should be as far as possible of one number. No. 7 and No. 9 frogs are largely used (the former corresponding to curves of 12°), as shown by the tables in the appendix. Frogs of lower number should only be used in special cases, but it must be remembered that the easier curves of frogs of higher numbers require longer leads and consequently more yard space. The Chicago, Burlington & Quincy Ry. uses a No. 7 frog in its 1 to 6 ladder tracks, putting a short curve beyond the point of frog. Complicated arrangements of switches, crossovers, etc., should be avoided. Slip-switches, though valuable and often necessary, are expensive in first cost and maintenance. The switchstands should be of good make and kept in good order, and if the numbers of the tracks are painted on the switchstands or targets the work

of the yardmen will be much facilitated. Usually the yard switches are worked independently, but in a large yard with heavy traffic it may often be economical to concentrate all the levers for the switches of a ladder track, etc., in a tower, instead of operating each one on the ground. These need not be interlocked, and the entire interlocking of yard switching is impracticable on account of the complication. The concentration of levers will simplify the switch movements. In the large yard of the Pennsylvania Ry. at Altoona, the switches are worked by compressed air, on the Westinghouse electro-pneumatic system. All movements are controlled by push-buttons in a switch board in front of the operator, and an indicator shows when each car has cleared its switch. The yard entrances should be equipped with interlocking signals and switches to ensure facility and safety in the operation of traffic. An ample supply of ties, slide plates, etc., should be provided for yard switches, and the whole yard should be well ballasted, well drained and kept in good condition, one or more men being detailed to clear up scrap iron, paper, refuse, etc. A difficulty experienced in most yards is that of keeping the surface of the yard neat and free from weeds. The yard gangs have other and more important work, and have little time for this incidental work, with the result that the surface gets irregular, and weeds grow thickly on little used tracks, making the general appearance of the yard unsightly.

The weighing of cars is a necessary and important item in yard work, but generally involves considerable delay and trouble. With the growing increase in the use of the tonnage rating system of making up trains, by actual weight of cars instead of number of cars, greater numbers of track scales are required. The Chicago, Lake Shore & Eastern Ry. has at its Chicago yard a track scale 100 ft. long, on which all cars entering and leaving the yard are weighed. The track has a down grade of 0.5% from 100 ft. in front of the scales to the storage tracks. Trains are pushed to the summit by switch engines, and each car is uncoupled and started in its turn, passing over the scales and being caught by a brakeman as it slows down before reaching the storage tracks. There is then no delay in stopping and starting each car on the scale. The cars are kept about 100 ft. apart, and in ordinary service a 40-car train can be weighed and switched in 20 minutes. Reference may be made to the failure to provide proper lighting for the yards, night work being done under adverse conditions by the aid mainly of small hand lamps. It must be admitted that the proper lighti of a yard is not an easy matter, owing to the interference of cars, whose black shadows alternating with lighted spaces, and moving from place to place, may be more dangerous than a uniform darkness to which a man's eyes become more or less accustomed. Nevertheless, the matter is not impossible of solution, and there are already some few yards which are efficiently lighted.

The discussion in detail of the design of individual yards can be of but little value, since the conditions and requirements, and the nature and extent of the traffic, are so diverse. What may be a desirable and economical plan at one yard may be entirely inapplicable at another. The freight yard of the Erie Ry. at Port Jervis, however, is shown in Fig. 144 as an illustration of some of the points discussed. The main tracks pass through the

Fig. 144.—Plan of Freight Yard at Port Jervis; Erie Ry.

middle of the yard, and the yard tracks aggregate 42 miles. The receiving yard for eastbound trains has five receiving tracks, and also two gravity tracks with a grade of 1.25% and about 800 ft. long, or of sufficient capacity to hold an eastbound train. At the bottom of this track are seven classification tracks, by which cars are sorted for transportation over the next division. By this arrangement, one man can sort 100 cars per day in station order.

The yard extends between block stations (J G) and (B C), a distance of 2.9 miles, and will hold 4,200 cars. Eastbound freight trains generally enter the yard at (J G) and are left there for classification. The three tracks nearest the main tracks in the eastbound yard are also "receiving" tracks, being used for that purpose when those at (J G) are filled. In this case the trains enter the yard at (W X) block station. The caboose is cut off at (J G) or (W X), as the case may be, and allowed to run down the main track by gravity to a caboose siding. The cars are classified in the "eastbound" yard, and thence taken in solid trains by yard engines to the "eastbound advance" yard, whence they are taken by road power to leave the yard at (B C) block station. The local cars are switched out and set on the four available tracks west of the "gravity yard," after which they are placed on the two "gravity" tracks which hold a maximum train. Westbound freight trains enter the yard at block station (P A). The cabooses are cut off about 1,000 ft. east of station (B C), and drop by gravity into the "eastbound advance" yard, whence they are taken as required by eastbound trains. The general operation of the "westbound" yard is about the same as that of the "eastbound," except that there are no gravity tracks. The track next to the main track, and the one on the extreme outside of this yard are kept open to facilitate the movement of engines to and from the coal pockets. Westbound trains leave the yard at station (W X). The arrangement of the yard is fairly satisfactory, but like most yards in this country, it has been developed from time to time without any special arrangement in view.

All connections with the main tracks are at the two block stations, so that these tracks can be fouled only at points protected by block signals. At the block tower at the entrance to the yard is a fixed red light, and the signalman is forbidden to show the hand green light until a train has slowed down for the red. This effectually prevents fast running through the yard. At the second tower in the yard (the yard being divided into four block stations), there is also a fixed red signal, with a green lamp below, lighted by electricity. This light is switched in by the signalman when notified that the block is clear, but the key is so arranged that he cannot fix it to display the green continually, as may sometimes be done by careless signalmen when a green hand lamp is used. It will be seen that trains are never given a clear signal through the yard, but only the green or caution signal. Where the block system is not used, freight trains should be required to stop at the yard limit sign, unless the track is plainly seen to be clear, and then proceed carefully into the yard, rear flagging being required within this limit, except when the freight train (or engine) is running on the time of a first-class train.

For city freight terminals, a problem of increasing importance is that of not only attaining efficiency and economy in the handling of cars and freight, but of attaining these ends on a minimum area of ground. In many cases it will be economical to abandon large city yards, selling the land or utilizing it for more remunerative purposes, and then to establish outlying yards on less valuable ground, with a limited number of tracks leading to central freight houses. To fully develop the area of these latter, the double deck system of freight houses, so generally used in Europe, may well be introduced. Cars are successfully handled on grades of 6 to 10% at coaling stations and even 25% at coal shipping piers, and are also very generally handled on curves of 50 to 100 ft. radius in yards, so that curves, inclines and elevators will enable tracks to be operated on at least two stories, with several floors above for warehouse or freight storage purposes. In regard to the economising of space in this way, English railway practice is largely superior to American practice. The great attention paid to this matter, in England, necessitated by the very high value of land, has enabled them to devise methods for handling enormous quantities of freight in city terminals of restricted area, while even the outlying and divisional terminals are laid out with greater care and with a greater attention to the operating side of the question than is common in this country.

In freight houses on piers, with a dock on each side, from one to three tracks are required down the middle of the pier, with trucking space on the outside, between tracks and edge of pier. Where warehouses are parallel with the wharf front, space can be economized by having tracks enter the building at the side, and run at right angles therewith or nearly so, and about half way across the width of the building. This method will give more car room, or rather more loading room, than where the track is parallel with the building. This is especially the case where the tracks are in pairs, say 12 ft. c. to c., with trucking space of 15 to 20 ft. between pairs, putting in as many sets of tracks as are needed. The ends of tracks should be within reasonable distance of wharf front to save as much as possible in the work of trucking, a very considerable item of expense in

handling freight. In Europe, hydraulic power is largely used for operating cranes, capstans, car elevators, turntables, etc., for handling freight at terminals.

It may be said without hesitation that on nearly every railway it would pay to have an extended and systematic investigation made as to the construction and operation of each important yard, and as to the means by which increased efficiency and economy can be secured; and then to follow such an investigation by a prompt and systematic undertaking of the improvements which are found to be desirable and practicable. Below are given extracts from a comprehensive paper by Mr. W. L. Derr, Division Superintendent of the Erie Ry., on "Railway Yards and Terminals," which was published in "Engineering News," New York, June 18, 1896. This paper discussed the principles involved in yard design, and yard work, and the points to be specially considered in a typical design. The details of the design of any actual yard should conform as closely as possible to the general principles and rules here laid down.

The following general proposition may be stated as a fundamental principle in yard working: Cars that are to be held at a yard must be kept apart from those in the regular movement, and separate tracks must be provided for the "hold" cars. To a violation of this principle, more plainly than to anything else, may be traced the delay to cars in yards, for, as will readily be seen, "hold" cars, when mixed in the regular movement, require a continual handling, having to be switched out every time the tracks they are on are worked. Yards otherwise poorly designed may often be operated in a fairly economical manner by providing storage tracks for the "hold" cars, both empty and loaded. It follows that, to secure order, separate tracks must be provided for cars of the different destinations.

All general movements of the traffic should be forward ones, and only under great stress are backward movements to be made. This point cannot be too firmly impressed upon those designing yards, as to neglect it will ever after cause great delay to the yard movements. Promptness in moving locomotives between the yard and the engine house is necessary, and the tracks should be so arranged that an incoming locomotive can, after placing its train on the receiving track, proceed immediately to the engine house. Where engines have to be changed quickly, as at division terminals in the case of the engines of passenger trains, a track should be placed near the changing point, for the accommodation of the incoming and outgoing engines. The coaling station, ashpits, sand house and water supply should be near the round house, and be accessible at all times.

A freight yard, of which a typical arrangement is shown in Fig. 14F, should have receiving tracks of the length, each, of the longest incoming train, for the reception of the trains as they arrive at the yard; "poling" tracks, if the poling method of switching cars is practiced (where there is not sufficient length of yard for poling tracks the "poling" can be done direct from the receiving tracks); classification tracks—one for each classification; advance tracks to receive cars taken from classification tracks, and upon which trains are to be made ready to be sent forward; short tracks, commonly called a "gridiron," holding from five to ten cars each, and used in classifying cars in station order for the division in advance; tracks for storing empty cars; tracks for "cripple" or damaged cars, and

tracks for cars with fast freight. "Poling" and classification tracks may be of any convenient lengths. For poling tracks, this would be about the length of an incoming train. For the shortest classification track, in order that switching may be continued during a temporary blockade of the main line in advance, it would be a sufficient length to hold the cars of that classification of several hours' working. Where there are advance tracks, the classification tracks may be somewhat shortened, but it must be borne in mind that the filling of one classification track blocks the classification of cars on all the others until the filled track is relieved. Spare tracks should, therefore, be provided near the classification tracks. Very long yard tracks are not desirable, for several reasons; among these are the high-speed required to pass cars to the extreme ends of such tracks (especially if the switching is done against a rising grade), and the great delay and consequent expense in returning the men to the switch engine after they have taken cars long distances. Separate tracks for stored empty cars should be provided in order to keep these cars out of the regular yard movement, which they would otherwise greatly complicate.

If cars with fast freight and those with slow freight are handled on the same classification tracks, they will become mixed, causing serious delay to the fast freight. The latter should be handled on separate tracks next to the main track in the classification or in the advance portion of the yard, or, better, a set of tracks in advance of all the other tracks, so that the fast freight will always be ahead of the slower. The care of disabled or "crippled" cars must be provided for, and the faster the traffic the greater the necessity for facilities for the prompt handling of these cars.

The tracks for cabooses or cabin cars should be so located that the cabooses can be got out of the way quickly on their arrival at the yard and yet will be accessible, without undue handling, to outgoing trains; and, if practicable, as soon as these cars arrive at the yard arrangements should be made to so place them. When there is room for it, a loop caboose track reaching from the receiving tracks, incoming, to the advance tracks, outgoing, will be found to be a convenient arrangement. When certain trains are run regularly by one set of crews and others by another it will facilitate matters to keep the two sets of cabooses separate, by providing a double caboose track.

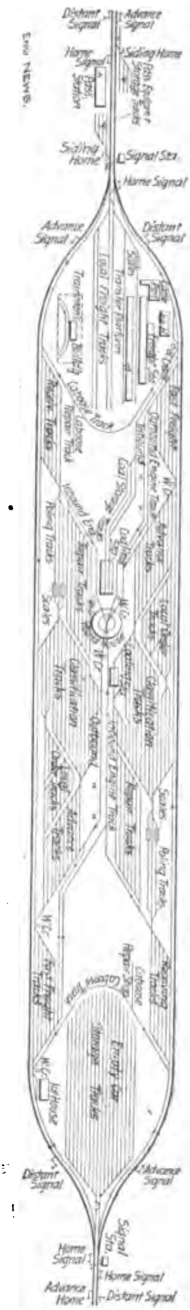


Fig. 145.—Plan of Typical Design for Freight Yard.

Heavy track scales should be placed at the entrance to the classification tracks, so that cars can be weighed while being switched. They should have a separate "dead" track, permitting cars that are not to be weighed to be passed over without affecting the scales. The location of scales for local purposes, will, of course, be governed by local requirements.

The location of the yard with reference to the main tracks is an important matter. The yard may be placed on the outside of each main track, or to one side of both of the tracks, or between them. The first plan is objectionable on account of the necessity of crossing the main tracks in passing from one side of the yard to the other; and the second on account of the traffic in one direction crossing the other main track to get into the yard. The third plan, that of placing the yard between the main tracks, is open to neither of these objections, and, if it further provides for the sufficient separation of the main tracks to make room for the engine house as well, the yard movements will not foul the main tracks from the time the trains leave the main tracks when entering the yard until they come on them again when leaving the yard. Main tracks so located should, when practicable, be placed far enough from the yard tracks to admit of additional tracks being built in the space, as required. At points where there are yard connections with main track the connections may be so arranged that ordinary switching movements will not cause the main track to be fouled when the switch is set for the main track movements. This may be effected by connecting the main track and the first yard track with a crossover and extending the yard track a short distance beyond the crossover, thus forming a "run-by." The "ladder" track is generally at an angle to the parallel tracks equal to the angle of the frogs, Figs. 144 and 218. When it is necessary to divide a series of parallel tracks without breaking their continuity, a straight ladder track with slip switches is run diagonally across them, the crossing of the tracks being effected by means of crossing frogs, and connections effected by slip switches, as in Fig. 53.

Where there is a large number of tracks, such as classification tracks, it may be advisable to make the entering end of the set wedge shaped in order to concentrate the switches and also to lessen the wear of the frogs and switches by trains crossing them. For the prompt operation of switches on the ladder track the levers for throwing them should be grouped, so that they can be worked by one attendant from a central station. This is not only the quickest but the safest method of operating the switches, because it avoids such misunderstanding as is apt to ensue if more persons than one handle a set of switches. The levers need not necessarily be interlocked. The switch lights are placed on stands near the points of the switches they govern and are turned by the movements of the switch rails. The lamps are provided with lenses of two colors indicating whether the switch is set for the ladder or the side track. Switch lamps should be placed close to the ground, so that they will not conflict with any block or interlocking signal in their neighborhood. The principles of signaling are the same in yards as on the line. At the entrance to the yard the main track switches should be operated from a central station and be interlocked with the signals that govern the main track movement and movements which may foul the main tracks.

Electric lighting is the best for yard illumination, provided the lights

are located with care. Electric lights cast a deep shadow, and unless they are located high over the tracks the shadows of cars and buildings near by will be troublesome. They should never be placed near an important signal, as their strong light obscures the weaker light of the signal. Electric lights make the best switch lights, also, giving a much stronger light than oil and requiring less attention in their care and maintenance. Water columns should be located at the engine house, at points where switch engines work, at coal pockets (if distant from the engine house) and at the outgoing ends of the yard. A main with hydrants about every 200 ft. should be placed along the receiving tracks for the use of car inspectors in cooling journals and in other work. There should be fire hydrants near important buildings and at points where cars are stored.

On rapid transit lines the headway, or interval between trains, is largely dependent on the arrangement of the terminal tracks, for in practice trains cannot be run on a headway less than the time used by a train entering and leaving a terminal. Any arrangement of track that makes it necessary to stop a train for the purpose of putting it in proper order as to engine or cars, or of putting it on the proper track for the outgoing trip, or that permits an incoming engine to be blocked in and thus necessitates an exchanging of engines, is defective so far as the running of trains at short intervals is concerned. Quick movements can best be made by arranging for the forward movement of the trains in all cases, and avoiding the necessity of having the traffic in one direction cross the traffic in the other direction.

The "loop" plan of track is the only one that fulfills the desired conditions. The loop, which is simply a circular track connecting the incoming and outgoing tracks, forms a continuous track to permit trains to pass from an incoming to an outgoing track by direct forward movement. No change in the arrangement of the train is necessary, and the locomotive is always run in the forward motion. By any other plan it is necessary either to run the engine backward (thus placing the engineman on the off side, away from stations and signals) during one-half its entire mileage, or else to turn the engine at the end of each run. In addition to the main line loop a sufficient number of tracks should be provided along it, or at least not far from it, for the purpose of storing the engines and cars which it is necessary to keep at the terminal. These additional tracks should be connected at both ends with the main track. Their exit ends should be far enough back of the starting station to make it unnecessary for a train, after pulling out, to back up in order to reach the station. The loop plan with forward movements, in Fig. 146, is, perhaps, the ideal loop track for this purpose, no backward movement being necessary in handling the ordinary traffic, either in passing from the main track to the side track or in returning to the main track from the side track. At points where there is not room for a loop, space should be reserved for terminal tracks of the usual order. If the room is so limited that even these cannot be accommodated, a trailing crossover should connect the two main tracks about an engine length from the end of the incoming track, so that an arriving engine can get out of the way without having to move against incoming trains or without having to wait for the train that it brought to be taken away. There should be another crossover a train length farther

back to admit of the passage of trains from the incoming to the outgoing track.

Items which make up the cost of yard operation are, besides interest on capital invested and depreciation, the cost of yard engine repairs and supplies, wages of yard enginemen, yard firemen, switchmen, yardmasters, signalmen, telegraph operators, way bill clerks and of trackmen, a percentage of general office expenses and of wages of train dispatchers, the cost of material used in track repairs, and the cost of labor and material used in the repairs of cars damaged in the yard.

Sand Track.

A sand track for stopping runaway cars and trains has its rails covered with sand, which rapidly absorbs the momentum on the treads and flanges of the wheels run into it. This system is used instead of derails at two junction points on the Chicago loop elevated electric railway, the length of track covered being about 100 ft. This will receive and stop trains which may pass home signals indicating "stop." The faces of the outside and inside guard timbers (6 × 8 ins. flat and 6 × 6 ins.) are both 6 ins. from the gage side of the rail head, and a trough is formed by 2-in. planks wedged

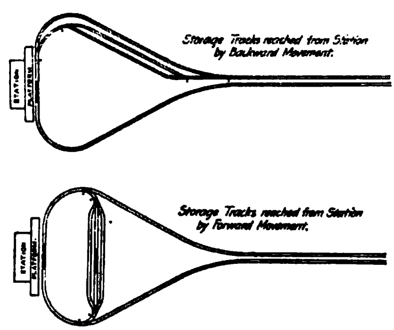


Fig. 146.—Loop Terminals for Rapid Transit Railways.

between the timbers and the bottom of the rail web, the joints being tarred. The sand just covers the rail head.

In the Friedrichstadt gravity switching yard at Dresden, Germany, about 20 sand tracks were installed for stopping cars in ordinary switching work, few cars having hand brakes. The grade of the switching tracks is 1%, and the resistance with 2 ins. of sand is about 0.0625% of the load, so that the sand track can take care of cars at a velocity of 14 miles per hour. The cars on the two gravity tracks of 1.8% down grade, leading from the gridirons of the classification tracks to the train tracks, are controlled by portable stop blocks (Fig. 135), which are placed upon the rails as required, men being stationed for that purpose. It was desired, however, to provide some means of stopping cars or trains which might get beyond control on the grade, so as to prevent damage to the cars, the freight or the yardman, and to prevent the possibility of collision with trains in the yard at the foot of the grade. For this purpose a sand track was adopted, gantleted with the running track, as shown in Fig. 147. The

latter track has main line rails laid on thick tie-plates, while the former has lighter rails, giving a difference of about 1.05 in. in height. Guard timbers are placed on each side of the lighter rail, and the space between them is filled with sand, covering the head of the rail by about 2 ins. for a distance of about 1,150 ft. If a car gets away, a yardman throws the switch of the sand track and the car is promptly stopped, while it is easily hauled back. On one occasion a freight train of 27 cars (with 55 axles), weighing 417 tons with engine and tender, got beyond control on the 1.8% grade, in spite of having brakemen on eight cars. It was diverted onto the sand track while running at about 30 miles an hour, and ran for 328 ft. over a thin layer of sand and 738 ft. over a 2-in. layer. After the train was stopped, the sand was cleared away and the train then ran on through the lower switch to the running track. The ends of the tracks in the

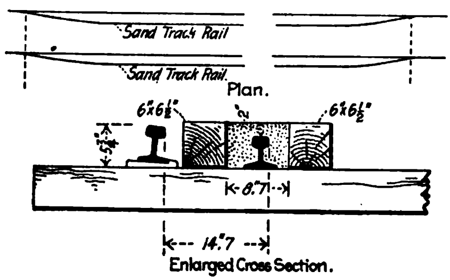


Fig. 147.—Sand Track for Stopping Runaway Cars.

Dresden passenger station are covered with sand, as an auxiliary to the buffer stops or bumpers, but this involves a loss of track room, as trains must normally stop before reaching the sand track.

CHAPTER 13.—TRACK TOOLS AND SUPPLIES.

The tools used in track work are an important item in the proper maintenance of way, and they should be of first-class quality, as these need cost but little more than inferior tools, while they do better work and have greater durability. It is bad practice and false economy to purchase the cheapest tools obtainable, and to neglect to see that the tools are properly and carefully used. The use of steel instead of iron enables the weight to be reduced in many cases, without reducing the strength or efficiency of the tools, and thus increasing the facility with which they can be handled. Tools with parts subject to wear should be bought under a guarantee that these parts are interchangeable.

Each section gang should have a complete equipment of the necessary tools and supplies. Special tools, of which only a few are required, such as rail saws, rail benders, etc. (averaging 1 to 50 miles of track), should be kept at division headquarters or other convenient points. Some roads also keep cross-cut saws, wheelbarrows, scoop shovels, etc., at these points, to be sent out to the section gangs for temporary use as required. A few

spare frogs and switch rails are usually kept at such points for emergency use. Two extra jacks on a division will usually be sufficient, but the New York, New Haven & Hartford Ry. has a special gang to do all work requiring the use of jacks, as noted below. On each division there will be a velocipede or inspection car for the roadmaster, and one for the engineer. There may also be the following for each division or a certain number of divisions: (1) A ditching car, with blades and mold boards for cleaning ditches and trimming ballast to the standard cross section; (2) A spreader car for leveling earth and ballast in widening banks, double tracking, etc.; (3) A steam derrick car of 8 to 12 tons capacity (and hoisting velocity of 1 ft. per second) for handling stone, lumber, etc., in emergency work or repairs; (4) a pile driver car; (5) a flanging car; (6) a snow plow; (7) a wrecking train. At division headquarters there should be a repair shop for repairing tools, frogs, and switches; for making guard rails, and for sawing and drilling rails for such work as can be done away from the place where it is to be used.

There should be a good supply of tools maintained constantly in the storekeeper's charge, so as to be ready to equip an increase of force in case of emergency, such as a flood, washout, snowstorm, landslide, wreck, etc. An accumulation of odds and ends of old articles and tools in the storeroom or the section tool house should be vigorously fought against. The cars of wrecking trains should always be kept fully equipped. Extra gangs will be equipped on the requisition of the division roadmaster, who will be held responsible for the return of the tools to the storekeeper. Roadmasters and foremen should see that no unserviceable tools are kept on hand, but that when damaged or broken they are sent at once for repair, or requisitions made for new ones. The section foreman is held responsible for all the tools issued for the use of his gang, and it is a good plan to have the tools of each gang plainly stamped with the number of the section. A close check should be kept on all tools issued, and not more issued than are properly required by the section, while, except for an increase of force, new tools should not be issued until those worn out or broken are returned, their disposal properly accounted for, or a satisfactory reason given for requiring the additional tools. A car should be sent over the division every month to pick up broken and surplus tools to be sent to the storekeeper, and the same car may collect the scrap from the section houses.

There should be some organized system for sending tools by train between the section and the shop or store. The ordinary tag on a bundle of tools is likely to be torn off or to have the address obliterated, and if this occurs on a bundle sent to the shop, the tools are either held or are sent out to some other gang, while the section to which they belong suffers from the delay. A good plan is to have brass disks or checks, like baggage checks, with the number of the section and name of station for that section stamped on one side, and the address of the shop on the other side. Two slots are cut at opposite edges for a leather strap, so that the strap can be slipped through to cover one side of the check, leaving the other side exposed to show the address to which the tools are to be sent. The checks for different divisions can be made of different shapes. The foreman should take a receipt from the station agent for tools shipped. The carying out of these check systems and the enforcement of the rules

above mentioned, will check carelessness, and result in a greater efficiency and economy as compared with the haphazard systems in force on some roads. Gages and levels should be periodically tested for accuracy. On the New York Central Ry. they are required to be sent in October to the Division Engineer to be compared with the standard in his office. They are then painted a distinctive color, so that roadmasters can see if the foremen have had these tools tested.

Each section should have a full equipment of good tools to supply every man, and some extra of such tools as have occasionally to be sent to the shop for dressing or repair. The number of these extra tools will depend upon the method of handling repair work and the frequency of the repairs required. The number of such extra tools should be specified by the roadmaster, and the extra tools should not be put in use until the regular ones have to be repaired or renewed. For sections having stone ballast it is recommended that there should be two tamping picks at the repair shops (or on their way there) for every pick in service. There should be a shovel for each man and the foreman, and two extra shovels. Proper supplies and appliances, oil, lamps, etc., should also be furnished, and all appliances not in regular use should be kept ready for service. The section house, lockers, etc., should be kept locked when not in use.

The foreman should see that the tools are taken care of, and properly used, not left on or between the rails, and not used for other purposes than those for which they were intended. He should also see that all tools and appliances are clear of the track before each train, and that the men do not wait until the last moment before quitting work in front of a train. Bars should not be thrown aside into the grass, where they are difficult to find, but should be stuck in the ground. Tools having bearings or cutting edges should not be thrown about on the ballast, where they are liable to damage by striking stones or other tools. The tools should always be taken to the section house at night, and not left out on the roadway. At the section house the tools should be placed on racks and shelves, or in tool boxes, and the sharp-edged tools kept carefully separated from the others. A little firm exercise of authority in disciplining the men as to the care and use of tools will result beneficially to the company.

Such tools as picks, bars, mauls, etc., are frequently made at the company's blacksmith shops, although they can usually be purchased ready-made almost as cheaply. The cost, however, varies with the skill of the men and the shop facilities, and whether the tools are made from new material or from the scrap heap of bridge rods, old tools, etc., always collected around a railway blacksmith shop. As a general thing, however, it is best to keep the scrap pile small and to purchase tools from reliable makers. The best design of tool should be aimed at, to secure the best service, and it is well to have as few different styles or makes of the same tool as possible. Clawbars and other heavy tools are often unnecessarily heavy, and of defective shape, while shovels are often too heavy and awkward to enable the men to do their best work with them. The desirability of adopting standard designs of track tools has been recognized by the roadmasters' associations, and some standard designs have been officially adopted, but the actual adoption of these standards in service appears to make but slow progress, as individual roadmasters apparently

still prefer their own familiar styles of tools, although they may have voted in favor of standard designs on general principles. Tamping machines have been tried experimentally.

For an ordinary section gang the equipment given in Table No. 15 will be generally sufficient, but, as shown, it varies on different roads, according to the ballast and other conditions of the track, as well as to the character and amount of the traffic. Ballast hammers, forks, and tamping picks are not needed with gravel or soft ballast. Besides the tools, each section will usually have about 50 to 100 bolts, 100 nutlocks, 200 spikes, 5 lbs. of nails, 5 lbs. of fence staples, 6 or 8 angle bars and a few extra pick or hammer handles. On a section where rocks are liable to fall, the equipment should include tools to facilitate their removal, such as rock drills or jumpers, stone wedges, blasting powder and fuse. When a special watchman is detailed to look after a dangerous rock cut, sliding bank, etc., he should be provided with a wheelbarrow, pick, shovel, ballast hammer, two flags or lamps, and torpedoes or fusees.

TABLE NO. 15.—TOOL EQUIPMENT FOR SECTION GANGS.

	Railways					Railways			
Article.	Chic. & N.W.	Erie.	Ill. Cent.	N.Y., N. H. & H.	Article.	Chic. & N.W.	Erie.	Ill. Cent.	N.Y., N. H. & H.
Spiking mauls	2	4	3	..	Bush hooks	2	1	..	..
Hammers:					Grub hoes	..	..	..	..
Ballast	..	..	..	..	Rakes	1	..	..	2
Trackwalker's	..	1	..	..	Hand car	1	1	1	..
Nail	1	1	..	1	Push car	1	1	1	1
Sledges	1	2	1	1	Track jack	1	2	2	..
Tamping bars	8	..	..	8	Track gage	1	2	2	2
Lining bars:					Center gage	..	..	..	1
Chisel point	..	3	6	..	Level board	1	1	1	1
Diamond point	6	..	..	6	Spirit level	1	1	..	..
Pinch bars	1	2	..	1	Tie square	..	..	..	1
Claw bars	2	3	2	3	Rail tongs	2	3	..	4
Spike puller	1	..	1	1	Tape line, 50 ft.	1	1	1	1
Picks	8	8	2	6	Ditch line, 100 ft.	1	..	1	1
Tamping picks	..	12	8	12	Wire stretcher	1	..	..	..
Scoops	6	6	..	7	Padlock and chain.	2	1	..	1
Shovels	7	6	8	12	Oil can	2	1	1	1
Snow	..	..	..	5	Oiler	1	1	1	1
Long-handled	..	1	..	..	Brooms	1	2	..	4
Ballast forks	..	..	6	6	Grindstones	1	1	1	1
Axes	1	1	1	..	Scythestones	7	2	..	4
Adzes	2	2	2	2	Wheelbarrows	..	2	..	2
Hatchets	1	1	2	1	W. pail and dipper	1	1	1	1
Track wrenches	4	4	4	5	Water kegs	1	..	1	..
Trackwalker's					W-wash brushes	..	2	..	..
wrench.	..	1	..	..	Tool boxes	..	1	..	1
Monkey wrench	1	1	1	1	Red flags	2	4	3	3
Punch	1	..	1	1	Green flags	..	..	3	3
Ratchet drill	..	1	1	1	White flags	..	..	..	3
Brace	1	1	..	1	Lanterns: Red	2	2	2	4
Files	..	1	1	2	Green	..	..	2	3
Chisels	6	10	3	10	White	2	4	2	5
Hand saw	1	1	1	1	Torpedoes	12	24	..	12
Cross-cut saw	..	1	..	1	Shims	..	Yes.	..	2,000
Scythes and snaths	7	6	4	8	Spike-hole plugs	..	1,000	..	1,000

Chicago & Northwestern Ry.—This list is not a standard, but represents the equipment of a gang of 7 men (including foreman) on a 3½-mile section on a double-track division with gravel ballast. There are two rail benders on the division, and instead of giving a ratchet drill to each section, there are three good drills which are sent out as required. Shims and tie-plugs are also furnished as needed. No grub hoes are used on this division, as the right of way is clear. A tool-box is only furnished to the extra gang.

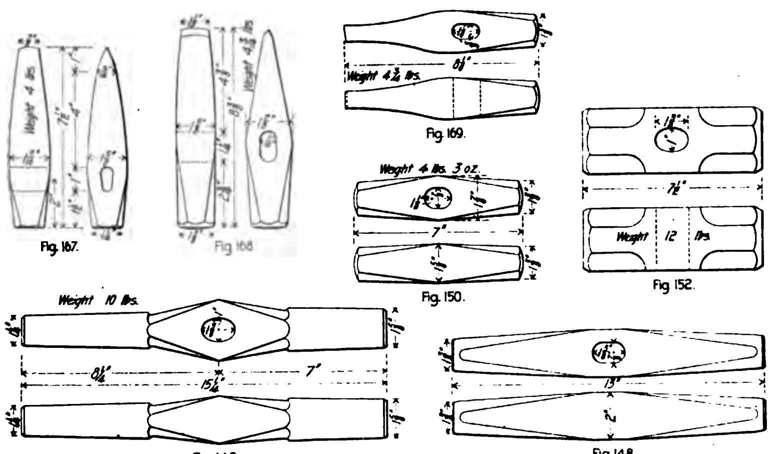
Illinois Central Ry.—The equipment listed in the table is for a gang of 7 men (including the foreman) on a single-track section 6 miles long, with stone ballast. The list varies on different sections according to local conditions.

Erie Ry.—The list represents the equipment for a gang of 8 men (including foreman) on a double-track section 5 miles long, with gravel ballast. The ratchet drill has four 1-in. bits and the brace has three ¾-in. bits. Each division has a rail bender at the shops.

New York, New Haven & Hartford Ry.—The equipment in the list is for a four-track section with 9 men (including foreman). No jacks are allowed, as their use on main line is prohibited except in case of emergency, when they are handled by an extra gang. The track wrenches are of the double-end pattern, and the ratchet drill has ¾-in. bits. The equipment also includes an elevator block.

Description of Tools.

Hammers.—The spiking maul of the Pennsylvania Ry., Fig. 148, has a head 13 ins. long, 2 × 2 ins. square at the middle and tapering to 1⅜ ins. diameter at the ends. Its weight is 11 lbs. Another form is shown in Fig. 149. The head is fitted to a straight wooden handle about 3 ft. long. The ballast or napping hammer, Fig. 150, is for breaking stone ballast, and is 7 ins. long, 1⅜ ins. diameter at the ends, and weighs 4 lbs. 3 oz. A lighter

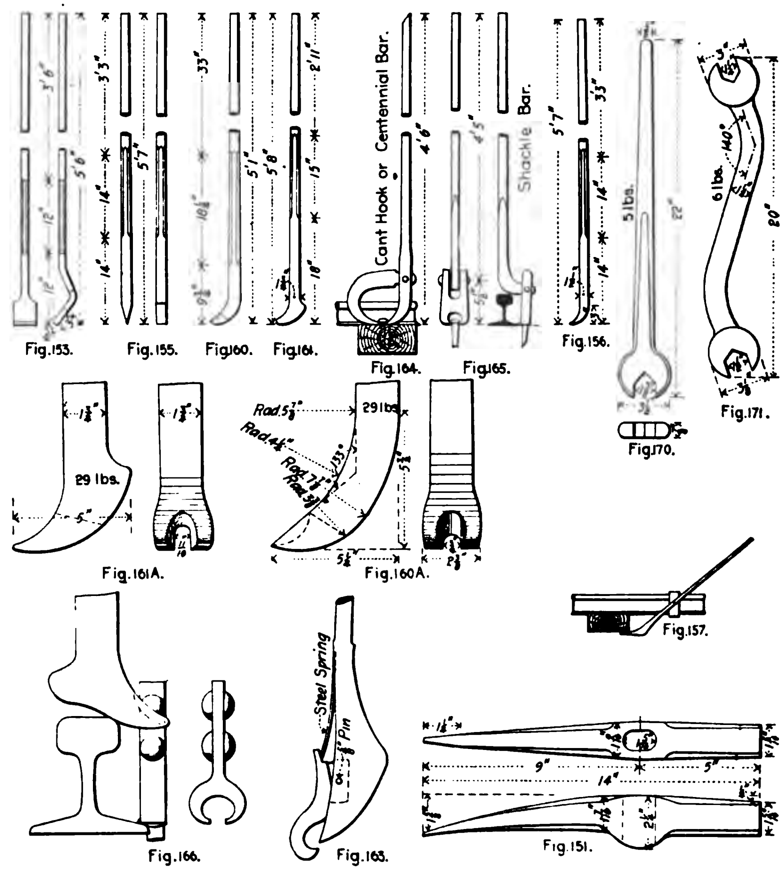


Track Tools.

one, 6½ ins. long, weighs 3 lbs. The trackwalker's hammer, Fig. 151, has a long head with a short handle. One end is curved and either finished to a point or to a 1½-in. chisel edge. The weight is about 14 lbs. The sledge has a short heavy head, set on a long, straight handle. It is used for knocking out ties and for striking track chisels, and foremen should see that spike mauls are not used for such purposes. The head, Fig. 152, is octagonal, with circular ends 2½ ins. diameter, and weighs 12 to 15 lbs.

Tamping Bar.—For tamping ballast (except stone or slag), a bar is used

about 5½ ft. long, weighing about 12 lbs. Two forms are shown in Figs. 153 and 154, the latter being the form adopted as standard by the Roadmasters' Association of America. The bar is generally of ⅞-in. round iron, straight, with a flat piece 6 ins. long and 4 ins. wide, ¼-in. thick at the edge, welded on at an angle of 24°, so as to strike well under the tie. The upper end should be flattened to a chisel edge 2 ins. wide. Some bars have the lower end bent, made ⅞-in. square, and having a tamping head 3¼ ins.



Track Tools.

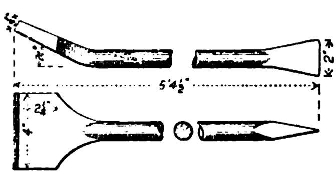
wide and ¾-in. thick. A larger diameter gives a better grasp for the hand, and in some cases a gas pipe handle is used to increase the diameter without increasing the weight.

Lining Bar.—For lining and throwing track, a straight bar is used, Fig. 155, generally about 5 ft. 6 ins. long, weighing 22 to 30 lbs., and tapering from 1½ ins. square at the lower end to ⅞-in. diameter at the top. A weight of about 24 lbs. is sufficient in a well made bar. The smaller end should be formed with a sharp diamond point, and the square (or lower) end should

have a 1¼-in. chisel edge for about 3 ins. In throwing track, the flat end of the bar is driven into the ballast, and two men can take hold of it. In some cases the pinch bar serves as a lining bar, as it answers very well for the purpose and thus saves the expense and trouble of extra bars.

Pinch or Raising Bar.—This is used for heavy lifting and prying up, and for raising and holding a tie for spiking or for slight raising of track, raising low joints, etc., although on some roads the track jack is used even for raising track very slight amounts. The bar, Fig. 156, is 5 ft. to 8 ft. long, weighing 26 to 40 lbs., and tapering from 1½ or 1⅝ ins. square at the lower end to ⅞-in., or 1-in. diameter at the top. The lower end is chisel shaped for about 3 ins., but sometimes the front face is vertical, only the back face of the chisel edge being inclined, while in the lining bar, Fig. 155,

Fig. 154.—Tamping Bar.



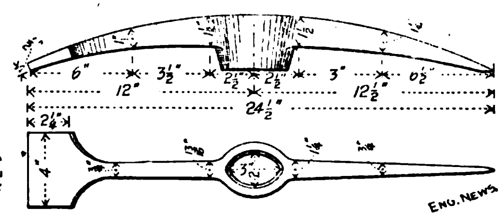


Fig. 174.—Tamping Pick.

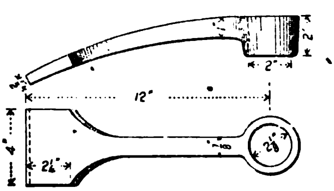


Fig. 175.—Tamping Puddle.

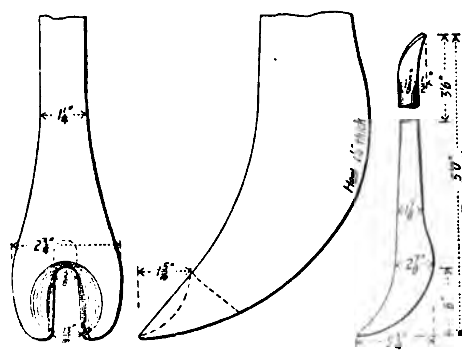


Fig. 162.—Clawbar.

Standard Forms of Tools Recommended by the Roadmasters' Association of America.

both faces are inclined. The end of the pinch bar is sometimes straight, but is more useful when slightly curved outward so as to get a good hold, and form a fulcrum when prying.

Holding-Up Bar.—In spiking rails it is customary to hold the tie up to the rail by a bar (or two bars) placed under the tie end, the holder-up either pulling up on the bar, or using a block for bait and bearing down on the bar. This is usually very ineffective, as in the former case the bar will sink in the ballast, and in the latter case much time is wasted in getting and setting the "bait" block; while the man will allow the bar to "give" every time a blow is struck on the spike. A handy tool which effects a considerable saving of time and labor in this work is a holding-up bar, Fig.

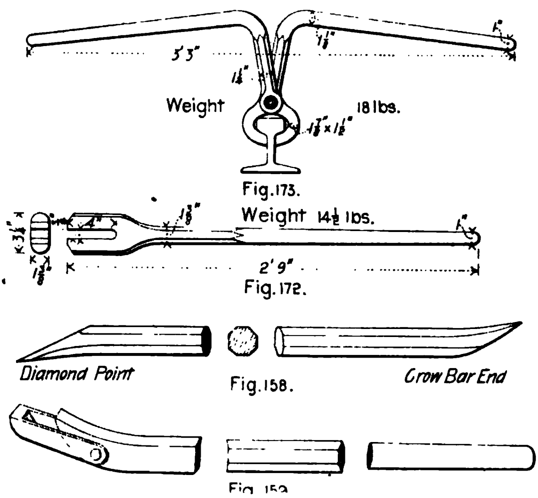
157. This is a pinch-bar with an inclined sharp, chisel-edged lower end to fit under the tie, or to bite into its side. To one side of the bar is pivoted an angle shaped piece, the horizontal part of which bears on the top of the rail, the bar being parallel with the rail. When the holder-up bears down on the end of the bar (which is parallel with the rail), he presses the tie up and the rail down, thus holding them firmly for the spiker. A shovel should never be used for holding up ties.

Bridge Bars.—Special bars are used for bridge work and two of the forms used on the Illinois Central Ry. are shown in Figs. 158 and 159. The former is for sounding and moving timber. The latter is for pulling out headless drift bolts, the shackle being slipped over the bolt and a bait block put under the heel of the bar to act is a fulcrum.

Clawbars.—For pulling spikes, a clawbar is generally used, ranging from 4½ ft. to 6 ft. in length, and weighing from 22 to 30 lbs. It is made in a variety of patterns, the body of the bar being usually about 1¾ ins. square at the ends, then 1¾ ins. octagonal and then of circular section tapering to 1-in. diameter at the top. Three forms of clawbar are shown in Figs. 160, 161 and 162. The lower end is curved outward at an angle of about 45°, and has a broad chisel edge with a notch to take the neck of the spike, the edge being struck under the back of the spike head. The distance from the point of the claw to the back of the bar is about 4 ins., and a block or "bait" is put at the back to serve as a fulcrum. Sometimes the back of the bar has a curved projection or heel to avoid the use of "bait," the distance from point of claw to back of heel being about 5 ins. Another form of bar, known as the "bull-nose" bar, has the lower end curved outward for a height of 6 or 8 ins., the radius being 5 or 6 ins. and the distance from edge of claw to back of bar being 4 to 6½ ins. The "gooseneck" clawbar has the lower end bent backward and then forward again in a reverse curve so as to give a long leverage in pulling, but as the claw is then nearly flat or at right angles with the bar, it cannot be struck under the spike head so well as a claw of 45°. For this reason it is best to use both kinds if much spike pulling is to be done, using the straight bar to start the spikes and the "gooseneck" bar to pull them out. In this way two men with bars can do more work and injure fewer spikes than one man with a straight bar, and another man to hold "bait." The clawbar adopted by the Roadmasters' Association of America, Fig. 162, is 5 ft. long, weighs 30 lbs. and has a curved chisel point at the upper end. The claw end has a spread of 5¾ ins. from point to back of heel, 6 ins. above the point. In using these bars care should be taken not to bend the spikes, a matter which is very often neglected by the foreman. If the spike is so driven that it is difficult to get hold of the head with the clawbar, it is better to chop away the wood with the sharp end of the bar, than to hammer the back of the claw to force it onto the spike.

Spike Pullers.—For pulling spikes in such places as on elevated railways, where the guard rails prevent the use of the ordinary clawbar; or at frogs and switches, on bridges and at stations, where these bars cannot well be used, a special form of bar or a spike-puller must be used. Fig. 163 shows a bar used on the South Side Elevated Ry., Chicago (whose track cross section is shown in Fig. 94), this bar having a loose hinged tongue and being worked parallel with the rails. The Manhattan Elevated Ry., of New York,

uses two forms of bars, as shown in Figs. 164 and 165. The shackle bar was devised by some of the employees and works very satisfactorily. The Verona spike puller, Fig. 166, has a rigid jaw which is slipped under the sides of the spike head, and a vertical stem with two projections to give a grip for a heeled clawbar, the heel of which rests upon the rail. This weighs about 1 lb. The Prout spike puller consists of a heeled bar with two loose claws hanging in front to catch the sides of the neck of the spike, while a bearing piece at the back rests on the tie and forms a bearing for the curved heel of the bar which rests on the rail head. The Welsh spike and bolt puller has pivoted claws, whose rear ends form a toggle engaging



Track Tools.

with a wedge in the heel of the bar, so that as the weight comes upon the heel the claws are forced to grip the spike. The movable jaws enable various sizes of spikes or drift bolts to be pulled.

Chisel and Punch.—Cold chisels used for cutting steel rails must be of good material, well made and well tempered, if they are to do much work. If too hard, they will break in use, especially in cold weather; while if too soft, they soon become dull and blunt. In winter it is well to warm them before using, and to strike the first few blows lightly. When only slightly dulled, and retaining their temper, they may be sharpened on the grindstone, but otherwise they must be sent to the shop. A good chisel should cut three or four rails, and the work should be done carefully, so as to damage the rail as little as possible. It is very bad practice to notch the rail with a chisel and then drop it on a block to break it, but sometimes the head is cut with a portable saw and the work finished with the chisel. Two forms of chisels are shown in Figs. 167 and 168, the latter being that adopted by the Roadmasters' Association of America, Fig. 168. The handle should be about 18 ins. long, so that the man holding it will be out of the way of the hammer. A properly made and fitted handle should be used, and not any rough stick that is handy. The steel track or rail punch for

hand use, shown in Fig. 169, weighs about 4¾ lbs. The head is about 8 ins. long, 11-16-in. square at the cutting end, which has a beveled face.

Wrench.—The ordinary track wrench is usually a steel die forging, about 15 to 24 ins. long, weighing 5 lbs. The handle is of 1-in. diameter, having one end flattened out for the jaw, and the other end shaped to a chisel edge or tapered to ½-in. diameter to put through the holes of rails and splice bars to bring them together. The jaws should have four sides, to conform in shape to a hexagon nut, and to fit a square nut. Figs. 170 and 171 show an ordinary and a double-end or S-wrench. Long-handled wrenches are sometimes used, but with a handle more than 26 ins. long a careless man can apply such force as to strip the threads of the nut or bolt.

Rail Fork and Rail Tongs.—These are used for carrying and handling rails. The fork, Fig. 172, resembles a long wrench, but with a slot ¾ × 4 ins. to receive the rail web or flange. The tongs are shown in Fig. 173, and are usually held by two men.

Picks.—Ordinary picks have heads about 2 ft. 2 ins. to 2 ft. 6 ins. long, weighing 7 lbs., and are fitted with straight wooden handles about 3 ft. long. The best picks have heads of solid cast steel, which will not split in the eye, but those made in railway shops are usually of iron, with cast steel ends welded on. The best refined iron should be used. A clay pick is about 1 × 1½ ins. at the eye, and one end is pointed, while the other end has a chisel edge 1⅛ ins. wide. The patent "eyeless" pick is made of a steel bar, having a malleable iron socket at the middle to which the handle is attached by a bolt. There should be three picks to every two men in the gang, to allow of their being sent to the shops for repair. The tamping pick, used for tamping stone and slag ballast, resembles the ordinary clay pick, except that one end has a flat tamping head. A steel pick 25 ins. long weighs about 8½ lbs. Fig. 174 shows the form adopted by the Roadmasters' Association of America. In another form the tamping end has the head gradually widening to shape from the eye, instead of having the plain shank with tamping head.

Tamping Puddle.—This is used for tamping gravel, cinders, sand and dirt ballast, and resembles the half of a tamping pick, the weight being about 5 lbs. The form adopted by the Roadmasters' Association of America is shown in Fig. 175.

Shovels and Forks.—Shovels of various forms are used for tamping and ditching, and for handling gravel, cinders, snow, etc. A good shovel is made from one piece of crucible cast steel, No. 12 gage, properly tempered, and having the straps strengthened by a taper socket for the handle extending about 2 ins. above the blade. The top should also be strengthened to prevent the breaking or splitting of the blade. Tamping shovels have blades approximately square and flat, about 10 × 2 ins. The handle is about 30 ins. long, and the total weight of the shovel about 7 lbs. In sand and gravel ballast the section-men will often tamp with the handles of their shovels instead of with the tamping bars, thus wearing and breaking the handles. The Shaw combined shovel and tamping bar was invented to provide for this practice, and has an iron shield over the wooden handle. Tamping shovels with malleable iron heads on the wooden handles are also used occasionally. Worn shovels may have the edges sharpened and be used for cutting weeds. Scoops are large full shovels for handling coal,

cinders, snow, etc. For digging post holes, long-handled shovels are used, having straight handles 4 ft. to 4 ft. 6 ins. long. Post-hole augers may also be used by a fencing gang. Special forms of long-handled shovels are used for deep holes for telegraph poles, and various forms of ditching spades are also supplied where there is much work of this character. Large flat wooden shovels are convenient for handling snow in yards. For handling stone or slag ballast it is well to use forks (like stable forks), having eight to ten tines or prongs, as this will eliminate the dirt or fine material which would be put into the track if shovels were used. The New York, New Haven & Hartford Ry. uses eight-pronged forks for handling stone ballast, furnishing one to each sectionman, an ordinary shovel being also furnished to each man for handling the finer stone and for ditching, etc.

Scythes and Hoes.—For clearing the right-of-way, etc., scythes and special tools are necessary, according to the material to be dealt with. The railway scythe for cutting coarse grass and light weeds, is slightly heavier than the common grass scythe. The bramble scythe is still heavier and the brush scythe is shorter and stouter. The bush hook is a stout straight blade with a curved end, used for cutting bushes, and is fitted to a straight axe handle. The grub hoe is useful in cutting roots, grubbing heavy soil, etc., preparatory to new work, and is also handy in ditching and for removing tough grass and weeds from the side of the track. It is about 16 ins. long, with two 3¼-in. cutting edges, one horizontal like an adze, the other vertical like an axe. The head weighs about 5 to 6 lbs., and has an eye to which is fitted a pick handle. Long-handled weed hoes are advisable where much weed cutting has to be done, as they are operated much more easily than shovels and save much back ache, thus enabling the work to be done quicker and to better advantage. This tool resembles a garden hoe, with a rather long blade set at about 150° from the handle.

Track Gage.—This tool is to give the required distance between rail heads in track laying, and to test the accuracy of the gage on existing track. Home-made gages with bars of seasoned oak or ash are used on nearly

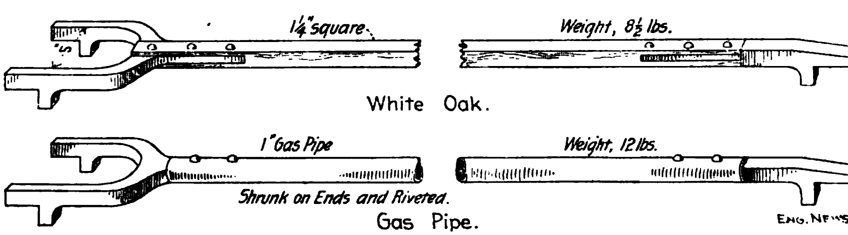


Fig. 176.—Track Gages.

every road, and have an advantage over iron gages in that they are not appreciably affected by temperature and are not liable to become bent (and consequently inaccurate). On the whole, however, an iron gage is probably preferable, but it cannot be used on roads having a track circuit for a block signal system, as it short-circuits the current and affects the signals in the same way as the wheels and axles of a train. This has led to a more extended use of gages with wooden bars, but of better construction than many of the old styles. In Fig. 176 are shown gages having steel

ends riveted to a white oak bar, and similar ends shrunk upon and riveted to a gas-pipe bar. To ensure rapidity and accuracy in testing the gage of the track, one end of the tool has a steel fork with two lugs, so that when both lugs are in contact with the gage or line rail the bar will be truly at right angles to this rail and the other lug will give the accurate position for the other rail. This is a similar arrangement to that of the well-known Huntington gage. The circular gage has at one or both ends an iron bracket curved to the radius of half the gage of track, so that it gives the correct width of gage even if the bar is not at right angles to the rails. On double track, a gage about 7 ft. long is used to test the gage relative to the center stakes. The gage invented by Mr. E. H. McHenry, Chief Engineer of the Northern Pacific Ry., provides for widening the gage on curves. At one end are pivoted five plates of ⅛-in. steel, which are normally held up by a clamp. One plate is turned down for each 3° of curvature, giving a maximum gage of 4 ft. 9⅛-ins for a 15° curve. On transition curves, two plates are turned down for each 3°.

Track Level.—This tool is for ascertaining whether the rails are in the same horizontal plane in tangents, or whether the outer rail has the proper elevation on curves. One form of the track level is a 1¼ or 1½-in. board, 5½ to 8½ ft. long, with a handle or hand-hole, and having a spirit level let into the top or side. One end is made with steps or offsets whose depth is equal to the elevation of outer rail for curves of different degrees, so that on a curve the spirit bubble is level when the bottom edge of the board is

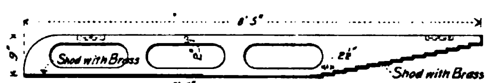


Fig. 177.—Track Level and Gage; Buffalo, Rochester & Pittsburg Ry.

on the inner rail and the proper offset is on the outer rail. The gage of this style used on the Buffalo, Rochester & Pittsburg Ry. is shown in Fig. 177. The board is 9 ins. deep for a length of 5½ ft., and then stepped off in offsets ½-in high and 2½ ins. long. This gives an elevation of 1 in. per degree up to and including 5°, and then ½-in. per degree up to a maximum of 7 ins. The offsets and the opposite edge of the board are shod with brass. The board is lightened by three openings about 5 x 12 ins., and has a spirit level at each end. A track level invented by Mr. McHenry, Chief Engineer of the Northern Pacific Ry., has at one end a steel blade moving in a vertical slot in the wooden bar. The edge of this is ground to an involute curve, and each face is graduated, the plate being adjusted by a thumbscrew. The level can be raised to give the full superelevation of 6 ins. while keeping the contact point of the plate constantly at the same relative position on the rail. The Sheffield duplex level has an arm pivoted at the center of the bar or board and resting against it. This has a spirit level on top, and the end forms a pointer moving over a scale on the side of the bar. When the arm is moved to set the pointer at any part of the scale, the spirit bubble will be level when the outer rail is raised the corresponding amount.

An excellent form of level board, which is also at once a track gage, guard-rail gage and track level, is shown in Fig. 178. It is a wooden board 1 x 4 ins., faced with an iron strip 3-16-in. thick extending over the bottom

edge, gage lugs and ends, and secured by screws. The length over all is 5 ft. 5¼ ins. The gage of track and guard rails is measured respectively over the outside and inside of the lugs, as shown, the lugs being 2 ins. deep and 1⅞ ins. to 1⅝ ins. wide. At the middle of the board is a hand-hole, with a spirit level tube set in the lower seat. At one end of the board is a plate sliding vertically in dovetailed guides, and held at any position by a nut on a ⅜-in. bolt. A graduated scale is marked on the slide, and in testing the superelevation of curves the slide is lowered to the amount of elevation required, this end of the level being then placed on the inside or low rail, and the outer rail then raised or lowered until the spirit level-bubble is in the center of the tube. By the attachment of a straight rod 3½ ft. long, held in position at the gage line by a semicircular arc, this tool is a great assistance in lining tangents. By making the iron strip in two pieces, separated by a space of about 2 ins. at the middle, the tool is sufficiently insulated to enable it to be used on roads having automatic signals operated by track circuits. The device was designed by Mr. J. W. Galbreath, Chief Engineer of the West Virginia Central & Pittsburg Ry., specially for the use of the track supervisors, but it was found to be so useful that it was made in somewhat lighter form and put in the hands of all the section foremen. For leveling one track with another, level boards 12 to 15 ft. long

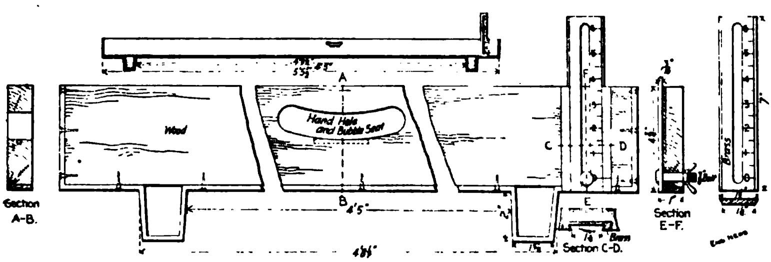


Fig. 178.—Track Level and Gage; West Virginia & Pittsburg Ry.

are used. The Boston & Maine Ry. gage is 14 ft. long, ⅞ × 6 ins., with strips ⅞ × 2 ins. along both sides of the bottom. One end rests on the rail of one track and the other rests on a leveling bob like a small screw-jack (6 ins. high when closed). A spirit level is set on top of the board, and adjusted until the board is level, the opposite rail being then adjusted accordingly.

Leveling Boards.—These are used for sighting when raising or surfacing track or taking out sags in the grade line. In some cases, three blocks of the same thickness are used, placed on the rail at the point to be raised and at the already surfaced portion on each side. A better plan is to have a white board (having a black stripe a little above its center), and two blocks, each as high as from the bottom of the board to the top of the black stripe. The board is placed across the rails at a point where the track is at proper grade. One block is placed on the rail at the point to be raised, and the other the foreman places on the rail at a point already at grade. The track is then raised until the middle block is sighted in line with the top of the first block and the stripe on the board.

Tie-Plate Gage.—The general use of steel tie-plates has led to the introduction of special tools for fitting them accurately, so as to give an even

bearing on the tie and correct gage when the rails are spiked through the holes in the plates. The gage invented by Mr. Ware, Roadmaster of the Buffalo, Rochester & Pittsburg Ry., is shown in Fig. 179. The bar (A) is of 1-in. gas pipe, having at one end a fixed head (B) and at the other end a sliding head secured by a thumbscrew clamp, this head being moved so as to give the correct position for plates of different sizes, the plate being set against the end of head (C) and its spur (D). The operations are described in Chapter 19.

Rail Benders.—These machines are now in general use, owing to the recognition of the necessity and advantages of doing this work accurately

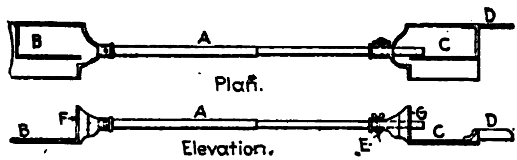


Fig. 179.—Gage for Setting Tie-Plates.

and without injury to the rail. It is very bad practice to bend rails by hammering them with sledges, or by dropping them on blocks, as such methods are more liable to kink the rail than to give it a uniform curve. Rails should never be nicked with a chisel for bending or straightening. In bending by the use of a curving hook and track lever, the rail is laid on its side, with its ends resting on two ties placed across the track rails, and the track lever is placed on the rail with its toe engaging a hook placed under one

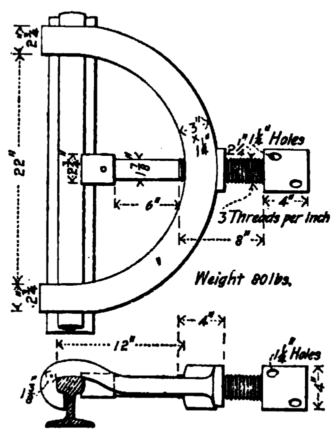


Fig. 180.—Rail Bender.

of the track rails. By bearing down on the free end of the lever the rail is bent as desired. Rail bending machines should be used for all rails to be bent to curves of over 3°. The ordinary jim-crow rail bender, Fig. 180, has a curved frame with hooked arms to hook over the rail head or flange, and pressure is applied to the rail head between the arms by a screw which is turned by a long handled wrench or by a bar fitting into the holes of a

capstan-headed screw until the ordinate for the required curve is reached, when the screw is slackened, the machine shifted along the rail, and the operation repeated. For heavy girder or T rails, the screw should bear against the web and head, a filler block being placed against the web. These machines are of various patterns, and weigh from 150 to 200 lbs. One of the best forms is the roller rail bender and straightener, as shown in Fig. 181, having grooved rollers on the arm to fit the outside of the rail head, and a third roller on the bending bar to fit against the inside of the rail head. The rail is first bent in the usual way, by setting up the screw with a long wrench until the middle ordinate for the desired curve is obtained; then the inner roller is turned by a long lever or a cross-handle wrench, causing the machine to travel along the rail, thus giving a uniform curve from end to end. To straighten a rail, the machine is put on the outer side of the curve. The number of men required depends upon the weight of the rail and the degree of curvature. For heavy rails, a horse may be attached to a long sweep or bar used instead of the socket wrench. In some rail benders the power is applied by an eccentric or cam, thrown

Fig. 181.—Roller Rail Bender.

by a long lever working in a vertical plane at right angles to the track. Hydraulic rail benders resemble the jim-crow in general form, but have a vertical hydraulic cylinder at the back of the frame operating the ram or plunger, which bears against the rail head. The ram may be run in and out for a few inches by hand, without pumping, thus allowing the machine to be readily placed on the rail and the ram brought up to its work, when a few strokes of the pump bend the rail to its desired curvature. The pressure is then reduced and the rail slid along for another application. The ram is graduated to show the extent of the bend and may have a loose head shaped to fit the rail head. The weight is from 200 to 275 lbs., and while this is more than the common screw bender the machines are compact and readily handled.

Angle Bar and Joint Press.—A jack or press is sometimes used to straighten angle bars which have become deflected or distorted, and a hydraulic press is also sometimes used for forcing the splice bars into posi-

tion on the rails to ensure a tight fit and uniform bearing. This latter device is more particularly used with very heavy rails and for deep girder rails.

Track Lever.—The track lever, Fig. 182, was the usual means of raising track until track jacks became of general application, and it it still used to some extent. It consists of an oak pole with an iron shoe which is put under

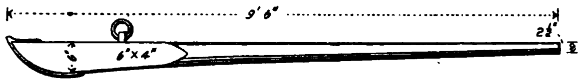


Fig. 182.—Track Lever.

the rail or tie and blocking placed under the heel, and then two or more men bear down on the free end. The method is clumsy and inefficient as compared with the use of jacks, as it requires several men, raises the track by jerks, and makes it difficult to adjust the amount of rise accurately. Even when the proper rise is obtained, at least one man must hold the end of the lever until the ties are tamped, and he generally slacks up on it in spite of all care.

Track Jack.—There are numerous varieties of track jacks, operated by ratchets, screws, friction clutches, hydraulic power, etc., and different

Fig. 183.—Friction Track Jack.

makes of these varieties may be found on most roads. A good jack must be able to sustain a heavy weight on the lifting bar, be positive in action, durable in design and capable of being relieved quickly of its load and removed almost instantly. For ordinary work they are about 24 to 30 ins. high, 7 × 12-in. base, with a rise of 12 to 15 ins., capacity of 8 to 15 tons, and weigh about 60 to 75 lbs. The lighter they are the better, as long as

they are of sufficient strength. One of the best forms of ratchet jacks is of the compound lever pattern, with two pawls (one of which is always engaged); it can raise or lower its load half a notch at each stroke, while it can be instantly relieved of its load. It may lift the head with the down motion of the lever only, or with both up and down motion. Hydraulic jacks are also used, and are generally filled with 2 parts alcohol to 3 parts water in winter, and 1 part alcohol to 4 parts water in summer. Water or kerosene should not be used, as water will cause rust and may freeze, while kerosene destroys the packing.

As track jacks are too high to go under the ties they lift by means of a claw hung from the head of the lifting bar, the claw being close to the bottom of the jack when lowered. The jack therefore reaches above the rail

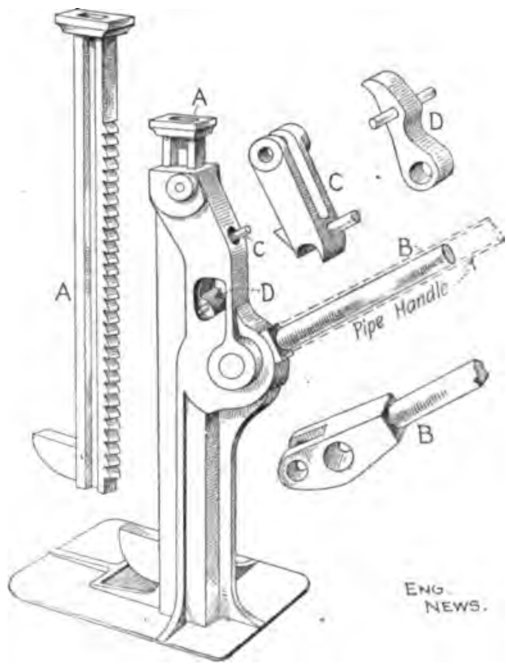


Fig. 184.—Ratchet Track Jack.

and may be a dangerous obstruction to trains, for which reason it should be made to release as promptly and easily as possible. The Fisher jack, which is little used, fits under the rail, and acts as a toggle. A lever turns a horizontal right and left hand screw (parallel with the rail) which passes through the lower ends of the toggle arms, while the upper ends (or apex of the toggle) carry a bearing plate which forms the seat for the rail or tie. This jack has a base of about 16 × 5½ ins., weighs 30 lbs., has a capacity of 15 tons and is only 7 ins. high at its lowest position. In the friction jack, Fig. 183, the link at the end of the working lever is coupled to a friction collar or ring, which grips the lifting bar. The upper ring encircling the bar is known as the lifting ring, and the lower one as the retaining ring.

The holes through them are bored at an angle, so that when horizontal they grip the bar, but when lowered they release it. These jacks for heavy ballasting, surfacing and general track repairs, have a 15-in lift. and a capacity of 10 tons, the jack being 35 ins. high when lowered, and weighing 90 lbs. A smaller size of the same capacity for short and heavy lifts in surfacing has a 7-in. lift, is 22 ins. high, and weighs 55 lbs. For light surfacing the jack has a capacity of 5 tons, a lift of 12 ins., is 31 ins. high, and weighs 60 lbs. The load can be lowered instantly or slowly. The ratchet jack, which is shown in Fig. 184, has a frame of malleable iron, with a base 7 × 12 ins., as recommended by the Roadmasters' Association of America. All the other parts are of crucible steel, with the exception of the loose pipe handle. The rack bar (A) has a sectional area of 1½ sq. ins., and is operated by the lever (B) and pawl (D), while the top catch (C) holds the bar in position at the height at which it is set. The load can be let down one tooth at a time when required, and can be dropped instantly and with certainty by the lower pawl, no independent trip being required. The jack is

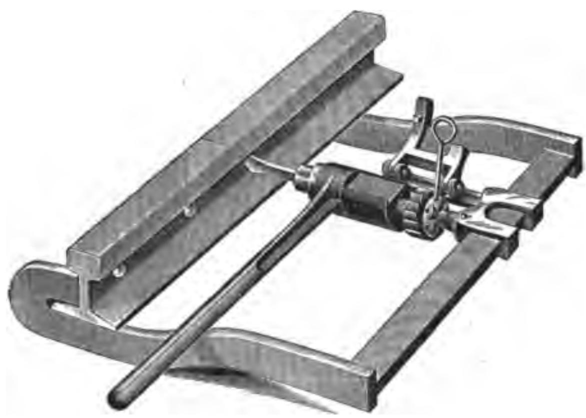


Fig. 185.—Track Drill.

21 ins. high, and has a lift of 14 ins., while its lifting capacity is 10 tons, and its weight 50 lbs. Hydraulic and screw jacks allow for very close adjustment on exceptionally good track.

On many roads, the jack is now used instead of the raising bar for small lifts, as in surfacing, etc., as well as for large lifts in raising lengths of track, while on other roads it is used only at frogs and switches, and for lifts of over 3 ins. The best practice is to raise both sides of the track simultaneously by the use of two jacks, and in general the claw should be placed under the tie and not under the rail, as in the latter case it tends to loosen the spikes. The jack should never be set on the inside of the rail, as in such position it is liable to derail a train, as was the case in the accident at Quincy, Mass., on the Old Colony Ry., in 1890, in which 23 persons were killed or fatally injured, and about 30 were more or less injured. The pilot of the engine caught the jack and threw it across the rail. If set outside the rail the man in charge is in less danger, and less likely to forget to release and remove the jack when a train approaches,

while even if the jack should be in place the engine would knock it away from the rail. The rules of some roads require that the jack shall always be used on the outside of the rail, no excuse being accepted for contrary practice, while the New York, New Haven & Hartford Ry. goes to the extreme of not issuing jacks to the section gang, but having an extra gang to do all work requiring the use of jacks. Where much lifting is going on, flagmen should be sent out to warn trains to run cautiously.

Track Drill and Punch.—Ratchet drills with automatic feed are generally used for drilling bolt holes in the rails, and in some of the various patterns several holes can be drilled at one setting of the clamp, the drill sliding along the frame, as in Fig. 185. The clamp should fit over the flange and

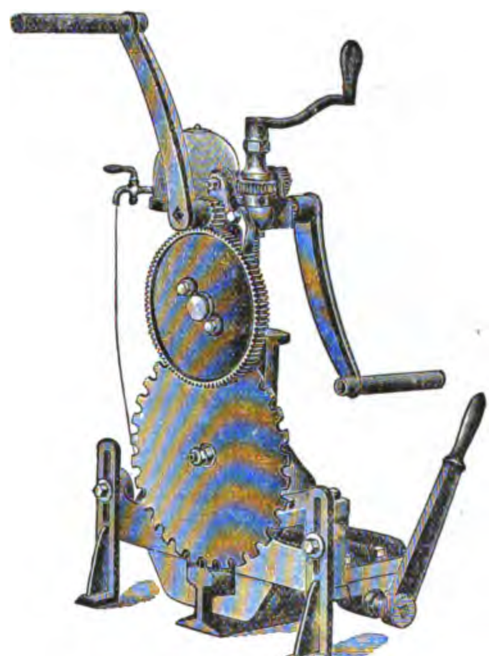


Fig. 186.—Portable Rail Saw.

not over the head of the rail, so as not to offer any obstruction to trains, and the drill carrier should slide on the frame so that the four or six holes of a joint can be drilled at one setting of the frame. In some of the ratchet drills the tool revolves with the movement of the operating lever in each direction, instead of in one direction only, as in the ordinary drills. They usually have 4 or 6 1-in. bits. In some drills the tool is driven by gearing and a crank handle instead of by a reciprocating lever and clutch. Portable hydraulic punches are used to some extent, the jaw fitting over the rail and having at its back a vertical hydraulic cylinder operating the horizontal punch. An adjustable guide at the top of the jaw insures all holes being punched at the same height in the same size of rail. These machines weigh

from 200 to 300 lbs. A vertical hydraulic punch for punching spike slots in rail flanges weighs about 90 lbs. Screw punches are sometimes used, those for heavy work requiring 2 or 3 men. A punch of this kind operated by 3 men, and weighing 80 lbs. has been used by the Buffalo Ry. for punching $1\frac{1}{8}$-in. holes in girder rails.

Rail Saws.—Rails are generally cut by means of a cold chisel and hammer, and too often they are partly cut and then broken by dropping them on a block, resulting in a rough and irregular rail end. Portable rail saws clamped to the rail are now being more generally used, and do better and quicker work, cutting a heavy rail in from three to ten minutes. The Higley and Bryant machines have circular saws operated by hand cranks and gearing, the saws being 14 to 20 ins. diameter. The former weighs 150 lbs., and the latter, Fig. 186, about 290 lbs. A good thin oil, such as lard oil, is recommended for lubricating the saw of the Bryant machine. The Smith

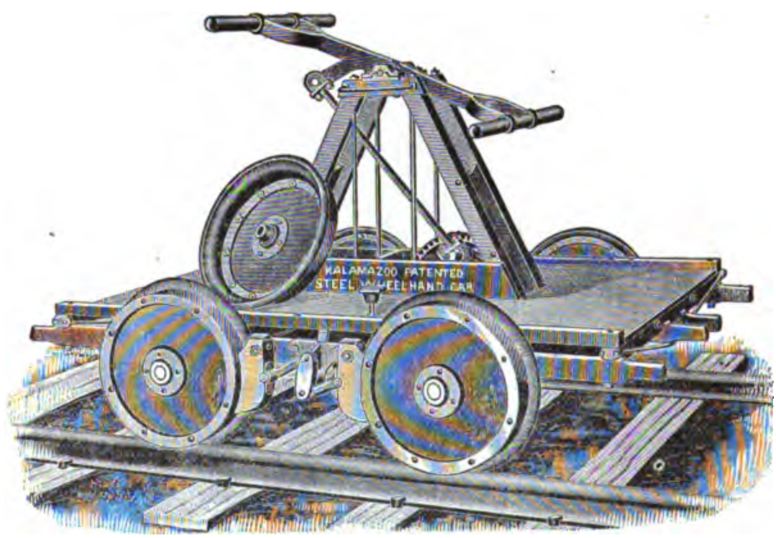


Fig. 187.—Hand Car.

machine has a frame about 3 ft. high, with a reciprocating saw blade worked by two levers like a fire pump or hand car. Its weight is about 120 lbs., and soapsuds are recommended for lubricating the saw, no oil being used in any case on the saw. With these machines very clean cuts are made and very thin pieces can be cut when necessary. Their use is particularly advisable on first-class track, for heavy rails and in fitting up frogs and switches.

Hand Cars.—These are sometimes made at the railway shops, but as a rule it is better to purchase them from firms making a specialty of their manufacture. Most roads forbid their use for carrying rails, except in case of emergency. The cars should be as light as possible, consistent with strength and durability, may have wooden wheel centers, or pressed steel wheels, and should invariably be fitted with a strong brake gear, generally

operated by the foot. Steel wheels are best for durability, but wood-centers are required on lines where a track circuit is used, to prevent the cars from operating signals in the same way as a train. The cars will ride more easily if one of the wheels (not on the driving axle) runs loose on the axle. Oil boxes should be frequently repacked, as the packing soon collects grit and sand. Roller bearings on the axles make the cars easy to propel. The car has a platform 6 ft. to 7 ft. 6 ins. long and 4 ft. 6 ins. wide, with a floor of matched planking and the ends of the sills extended to form handles. The wheels are ordinarily 20 to 24 ins. diameter. The weight is from 475 to 575 lbs. The car is generally driven by a lever or walking beam pivoted at the middle and having a cross handle at each end, so that four men can work it, the spur-wheel being worked by a crank with a connecting rod from an arm on the walking beam. The spur-wheel gears with a pinion on the axle, the gearing being usually about 3½ to 1. These cars will carry ten

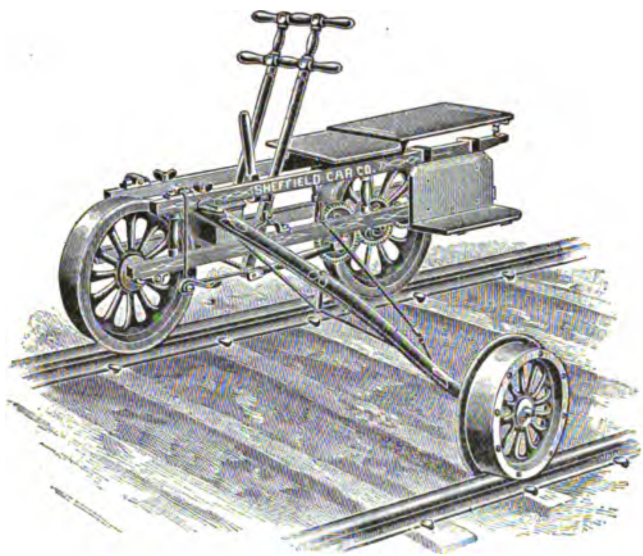


Fig. 188.—Track Velocipede.

or twelve men, with tools, etc. They are sometimes operated by a sail, which method is particularly applicable for western roads with long tangents, as steady winds usually prevail. The hand car shown in Fig. 187, weighs about 550 lbs., and has 20-in. steel plate wheels on 1½-in. steel axles, with a 4-in. bearing roller secured to the underside of each sill. The gears are 2¾, 3⅓ and 4 to 1; the first is used where much power is required on account of steep grades, and the last where high speed is desired on level roads, while the second is generally employed for ordinary work. A weed-cutting hand car is described in Chapter 19. When not in use, the cars should be taken off the track and placed clear of the track. It is best not to leave them near road crossings, and if left there or at any distance from where the men are working the wheel should be secured with a chain and padlock.

Track velocipedes are light three-wheel or four-wheel hand cars, weighing 120 to 250 lbs., which the operator propels by a hand lever, treadle or both. In three-wheel cars, Fig. 188, the third wheel is carried at the end of an arm which is hinged, so that it can be folded back against the other wheels for convenience of shipment in a baggage car. These cars are used by roadmasters, inspectors, foremen, etc., and on some roads by a man who rides over the track daily instead of trackwalking. The car may be fitted with an odometer for measuring distances. Some cars of this kind have been equipped with sails and worked satisfactorily, but care is required in handling them. Hand cars fitted with seats are used for inspection purposes, and some of these cars are operated by small steam engines, while velocipedes operated by gasoline engines are now quite extensively used. Some of the most recent velocipedes have frames of bicycle tubing, with wire-spoke wheels, and have the bicycle style of saddle, handle bar and driving gear. Some of these weigh only 75 to 100 lbs.

Push Car and Rail Car.—The push car is a platform car not fitted with propelling gear, and is used for carrying rails, ties, gravel, earth, supplies, tools, etc. The car in Fig. 189, with a platform $7 \times 5\frac{1}{2}$ ft., and four 20-in. wheels, will weigh 450 to 500 lbs. The rail car or tracklaying car, Fig. 197, has no platform, but two side sills, to which the journal boxes are attached,

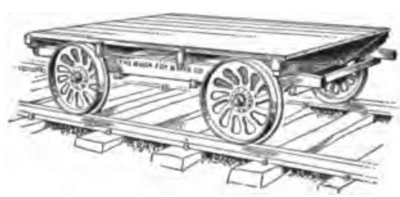


Fig. 189.—Push Car.

and three or four cross timbers faced with iron. At each end are two rollers to facilitate unloading rails. A rail car 8×6 ft., with sills 4×8 ins., wheels 16 to 20 ins. diameter, $2\frac{3}{4}$-in. axles, and a carrying capacity of 10 to 12 tons, will weigh about 1,000 to 1,350 lbs. A plank bottom may be nailed to the underside of the middle cross sills to form a box for tools or supplies.

Flags.—The ordinary flag is not reliable as a signal when the staff is stuck in the ground; if the weather is calm it hangs limp, while the wind may blow it parallel with the track or wrap it round the staff. This may be remedied by having it attached to a staff at each end, or the staff may be fastened horizontally to a post 4 ft. high, 8 ft. from the rail. In the Tallman device the flag is wound on a roller in a cylindrical case, having a slot for the flag. This case is hinged at one end to the staff and when not in use folds against it (with the flag inside), while when in use the case is horizontal and the flag displayed. Some roads require a flagman to hold the flag always in his hand, but where a flagman is not stationed, a flag with two staves, or with some means of keeping it displayed, should be used. Iron flags or targets have been used. Flags should be kept as clean as possible, and replaced when so torn or dirty as to be unreliable as signals. When not in use they should be rolled up and tied with string.

Lamps.—The ordinary lamps are of use as signals, but not of much use for work on the track, giving too poor a light. They should be kept well trimmed and filled, and placed on a shelf out of the way so as not to be broken in handling the tools. A few spare globes should be kept on hand. The oil cans (usually of 2 gallons capacity) should be set in a wooden box or tray filled with sand, and some oil should be kept on hand when the cans are sent to be refilled. Signal oil for switch lamps, which has become thick, may be thinned with kerosene.

Miscellaneous.—Wheelbarrows may be of wood or iron, the former being more readily repaired on the section. They should be substantially built, with strong axles and bearings, and will require occasional oiling of the axle. In ditching work, a wheelbarrow with grooved wheel to run on the rail is sometimes used. Heavy garden or farm rakes are used for clearing up brush, trimming station grounds, etc., and wooden rakes may be used if hay is made from the grass cut on the right of way. Ordinary flat corn brooms are used for clearing snow from switches and frogs, cleaning ties after adzing for new rails, and also for sweeping out the section house.

CHAPTER 14.—SIGNALING AND INTERLOCKING.

The supervision and care of the signaling and interlocking equipment is now frequently under the charge of the roadway or maintenance department to a greater or less extent, and the general principles and practice may be appropriately considered. The details of the mechanism, apparatus and operations controlling the various movements of trains, however, would occupy far more space than is now available. The fixed signals governing train movements, independent of the switchstand targets, may be classed as route or switch signals, train-order signals and block signals. The first are used at turnouts, junctions, etc., to indicate for which track or route the switches are set, and also to indicate to an engineman whether the route which he wants is set for him. Train-order signals are located at stations, to indicate whether a train is required to stop for orders as to its movements. Block signals take the place of train orders, and indicate whether the block sections into which the line is divided are clear or occupied by other trains. Interlocking signals comprise both switch and block signals, and, properly, they should not be separately classed. In this country, however, many interlocking plants are installed at crossings, etc., on lines where the block system is not in force, and this has resulted in creating a distinction between block and interlocking signals. In effect, the limits of the interlocking plant enclose an isolated block. Interlocking plants and the block system are in use to some extent on electric railways.

Under the train-order system of operation, the dispatcher on the division issues telegraphic orders to the trains to run between certain points, stopping at specified places for further orders. He can stop the train for orders at any station by notifying the telegraph operator or station agent to display his "stop" train-order signal. Following trains are required to

be held a certain number of minutes apart, forming a "time interval," which cannot always be maintained, and is the cause of many accidents. The better system is that known as the block system, under which the line is divided into sections or blocks, the limits of which are marked by signals, so that the trains are periodically advised as to the safety of the line ahead. Its great advantages are facility and safety of operation, for as no two trains are normally admitted to the same block a "space interval" is maintained between all trains, so that collisions are impossible. With the "absolute" block system, no train must be admitted to a block section until that section is clear or empty. The "permissive" block is a modification under which a second train may be admitted after a certain "time interval," a caution being given to proceed carefully, as the block is not clear. This is dangerous, however, and at once eliminates the great element of safety due to the "space interval." It has been adopted in some cases for freight trains only, with a view to facilitating traffic, but in some of these cases it has eventually been abandoned, since ample facilities and much greater safety can be afforded by the "absolute" block system. The block system is extensively adopted on both single and double track lines. The length of the block sections varies greatly, depending upon the amount of traffic, the curvature, switches, stations, passing places, etc.

Block signals may be operated on either of two systems: (1) Manual (with "lock and block" modifications, (A) controlled-manual, and (B) auto-manual); (2) Automatic. In the manual system, a tower or cabin is erected at the end of each section, there being telegraph or telephone connection between adjacent towers, and the signals at each tower being operated by the signalman in accordance with information or instructions given by the next man in the rear and in advance. In the controlled-manual system, the signals are automatically locked in position and the locks are controlled from the tower in advance, so that a man cannot show a "clear" signal until the signal is released by the next man. In the auto-manual system, the "clear" signal is automatically returned to and locked at "stop" by the entrance of a train into the block section, and is not released until the train has passed out of the section. This locking is effected by a mechanical or electrical device termed a "slot." A combination of the train-order and block systems of operation is sometimes used, under which the train-order signals at stations are utilized as block signals, but under the direction of the dispatcher. This combination has also been applied to the ordinary system of blocking with intermediate towers and signals, but this method has very little to recommend it, the traffic being handled with greater facility by the series of signalmen or operators. In the automatic system, no towers or signalmen are required at the block signals, but these are operated by the trains, by means of electrical or mechanical connections or track instruments. A wire circuit or rail circuit may be used, but the latter is most generally used, and has the advantage that a broken rail, etc., will cause the signals to indicate "stop." Where a rail circuit is used, the rails of each section are connected by bond wires, and insulated joints separate the sections from one another. Section men must be careful not to bend or cut the wires in doing their work.

Automatic signals may be operated entirely by electricity, or by a com-

bination of compressed air and electricity. In the latter system, the valves of air cylinders attached to the posts are operated by the electrical connections, the actual movement of the signal (and of the switch, in interlocking plants) being affected by the air, which is carried in a line of 3 or 4-in. pipe laid along the side of the roadbed or buried between the tracks. The pressure is usually 80 to 90 lbs. Overlapping or double blocks are sometimes used. In the former case there are two distinctive signals at each block. As a train passes into a block it throws both signals to "stop," protecting its rear, but releases one of the signals of the section behind. In the latter case only one signal is used, but there are always two signals at "stop" behind the train, so that a following train can never come within a block length of the train ahead.

The automatic system is being very extensively adopted in this country, even for lines with very heavy and fast traffic, and the ideal system for controlling trains on lines with heavy traffic and high speeds was suggested as follows by Mr. E. C. Carter, Chief Engineer of the Chicago & Northwestern Ry., in a report prepared for the International Railway Congress of 1900: "(1) Interlocking plants at all points where there are switches on the main tracks, the home or advance signals being electrically slotted with a track circuit through the succeeding block, the towers to be supplied with indicators to give information regarding trains in the adjoining blocks. (2) Automatic block signals placed as required to properly space trains moving between the interlocking plants. Such a system will admit of the heaviest traffic movement, with the greatest safety, with the least detention, and at least cost for protection."

Train-order signals are very frequently targets mounted on the platform shelter or on a post in front of the station, but the semaphore type is preferable and is now very generally used. They are operated by levers at the operator's table or desk, and if used as block signals will be normally set at "stop." Switch signals are usually of the semaphore type. Block signals are of three types: semaphore, disk, and banner or target. The first is by far the most generally adopted, and is used with both the manual and the automatic systems. The other two are used almost exclusively for the automatic system, and the banner type is only used to a limited extent. Two positions are usually employed. With the semaphore signal, the horizontal position of the arm means "section occupied, stop;" and any position below the horizontal (usually 60° to 90°) indicates "section clear, proceed." In some cases a third position is introduced for permissive blocking, the arm being inclined 60° below or above the horizontal to indicate "section occupied, proceed under control;" if the position is below the horizontal, the arm then hangs in a vertical position to indicate "section clear." It is much better, however, to have only two positions, and to issue a clearance card cautioning the train to proceed carefully, when it is imperatively necessary to send it on without waiting for the section to be cleared. With disk signals, the disk is enclosed in a "banjo" box on a post, and when it is visible at an opening in the face it indicates "stop," while its absence indicates "proceed." With slow-speed service, the only signal necessary would be one at the entrance to each section, but with the high speeds of every day practice it would be impossible to stop the train at a signal after it came in sight. Distant signals

are therefore provided, set at least 2,000 ft. in advance of the main or "home" signal. When this signal indicates "clear," the engineman knows that the home signal is also at "clear" and that he has a clear track through the block section which he is approaching. The other position of the distant signal does not indicate "stop," but only "prepare to stop at the home signal." It indicates to the engineman that the home signal is at "stop," and while the latter may be moved to the "clear" position before he reaches it, he must get his train under control ready to stop at the home signal if it has not been cleared. Trains held at a home signal are often allowed to pull past it so that the signal will protect the rear of the train, in which case an "advance" signal is put about a train-length beyond the home signal, so as to indicate to the engineman when the block is clear. On single track, however, trains must not pass the home signal until it is clear. The arrangements of automatic distant signals have already been referred to. Signals are usually kept at the "stop" position except when it is necessary to give a "clear" indication to a train, but in some automatic signal installations, the signal returns to the "clear" position as soon as a train has passed out of the block.

Semaphore signals usually have the face of the arms of home and advance signals painted red with a white square near the end, while those of distant signals are painted green with a white square or V stripe, the end of the blade being notched or fish-tailed. Others use white with a black square for the running face of home signals, and yellow with a black V stripe for distant signals. Still others use yellow with a black square or black fish-tailed stripe for the running face of all signals. The object of this is to have the indication of the signal given by position and not by color. With disk signals, a red disk for the home and a green disk for the distant signal is the usual practice. Signals at interlocking plants are almost invariably of the semaphore type, but where this type is also used for block signals, a distinctive form is sometimes adopted by making the arms of the latter pointed, with V stripes. This is done for the reason that an engineman must never pass a "stop" signal at an interlocking plant unless he has definite and positive orders and a "clearance card" from the signalman. A block signal, however, may be out of order, and if it is not "cleared" in a few minutes, the train may proceed carefully, expecting to find a train, broken rail, etc., in the section. Very often, the station block signals are on a single post opposite the station, but it is much better to have each signal on its own post at the proper end of the station.

The night indications are given by colored lamps. The old plan was to use red for "stop," white for "clear," and green for "prepare to stop" on the distant signal. Owing to the confusion of white signal lights with street lamps and other lights in towns and cities, and to the possibility of a "stop" signal indicating "clear" by the breaking of the red lens, the most approved system now is to use the green light for clear. This, however, has made necessary a new indication for the "prepare to stop" position of the distant signal, and two methods have been adopted: (1) to use two lenses (with one lamp), the signal showing a green light for "clear" and a green and red light side by side for "prepare to stop;" (2) to use a distinctly yellow (not white) lens. The latter is preferable, as it avoids

the use of a double light for one signal. The former was introduced by the Chicago & Northwestern Ry., and the latter by the New York, New Haven & Hartford Ry. In disk signals, the lamps show a light through an opening in the case, colored lenses inside being moved in accordance with the movement of the disk. A purple light is sometimes used for "stop" on minor signals and for the "dummy" posts indicating unsignaled tracks where bracket posts are used. To indicate whether the signal lamp is burning, a small opening is put at the back of the lamp, and shows white when the signal is at "clear" and purple when it is at "stop." It has been proposed, however, to use a purple bull's-eye only, no light being shown during the short time that the signal is at "clear." The lenses are usually 6 and 8 ins. diameter, with a 2-in. bull's-eye for the backlight. (See Chapter 7, "Lamps.")

The home signal is usually 50 to 200 ft. from the point it governs, and the distant signal 1,500 to 2,500 or even 3,000 ft. beyond. Very long spacing, however, requires reliable compensators, which are few and expensive. Derails at crossings are 300 or 400 ft. from the crossing, or 150 to 300 ft. from back-up derails (See Chapter 9, "Track Crossings"). In isolated cases, as at crossings with very light and slow traffic, the distant signal may be dispensed with, for economy, a sign being substituted to notify an engineman that he is approaching the crossing and must be prepared to stop at the home signal. This practice cannot be adopted at busy crossings with high speed trains, as it would not only be unsafe, but would cause serious detentions by checking every train. Signals should be set directly over the tracks governed (on bridges) or at the right-hand side (left-hand when trains keep to the left). If tracks are too close together for the signal to be set at the side, a bracket post should be set at the right of the outer track. This has a platform carrying posts of different heights, the highest indicating the high-speed route. If there are two tracks there will be two posts on the platform, but if the inner one is a sidetrack and not signaled, then the low post corresponding to this track will have no arm and will carry a purple light at night. The arms point away from the track governed, and there should be not more than two arms on the same side of the post. When the signals are at stations, the two arms are very generally mounted on opposite sides of the top of one post in front of the operator's office. All switch signals should be included in the block system. If for economy or other reasons this is not done, then a target should be used, entirely distinctive from the block signals.

The term interlocking should include the locking of the block instruments and apparatus of adjacent towers, but is commonly confined to the interlocking of switches and signals at junctions and crossings in such a way that they cannot be set for conflicting routes or to cause collisions. Thus in the case of a single track Y-junction (A), where two lines (B-A) and (C-A) unite to form one line (A-D): If a train is running from (C) to (D) it cannot be given a clear signal for the junction until the signals have been set to stop trains approaching from (B) and (D) and the switches have been set for (C-A-D). Distant and home signals are used, and when the train has passed the former and entered the limits of interlocking, the signalman cannot move any signals or switches of this or conflicting routes

until the train has passed beyond the limits. This locking of the home by the distant signal at "clear," should never be applied to block signals, as the signalman should have it in his power to stop a train at any time before it has actually reached the signal, in case of emergency. On the other hand, it should not be practicable to show a clear distant signal until the home signal is at "clear," and at interlocking plants it must be returned to "prepare to stop" before the home signal can indicate "stop." The interlocking should be so arranged that a home signal cannot be shown at "clear" until derails or diverging switches in conflicting routes are in their normal position and the switches for the required route are set and locked. The home signal when at "clear" should lock all switches and locks in the route as far as the point to which the signal gives permission to proceed, locking all opposing or conflicting signals and releasing the corresponding distant signal.

It would be impossible to deal with the details of locking and interlocking apparatus in this chapter, but it may be noted that switches are usually locked by bolt locks, a typical arrangement of which is shown in Fig. 190. The head rod of the switch, or a rod extending from it beyond the rails, has two holes, engaging with a horizontal bolt or plunger moving parallel with the rail in a casting on the tie. When the switch is properly set in either position, the bolt is thrown and enters the hole, the movement of its

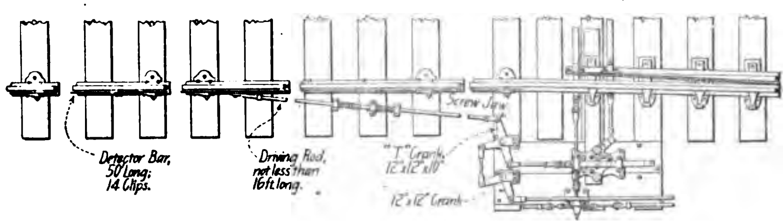


Fig. 190.—Bolt Lock for Switch.

operating rod unlocking the lever of the signal governing the switch. If the switch is not properly set, the bolt cannot enter and consequently the signal remains locked at "stop." When the switch is locked, the bolt cannot be withdrawn while a train is passing, a detector bar preventing the movement of the operating rod. The bar is at least 50 ft. long, so that one wheel of a train will always be over it. It is hinged on studs and lies against the outside rail head. In moving it has a longitudinal motion, and rises slightly above the rail head, which it cannot do as long as a wheel is on the rail. These bars are very extensively used in interlocking work.

The switches, signals, locks, etc., are operated from the upper story of the tower by means of L or inverted T levers, the upright end working between sector guides in the floor. A latch handle against the lever handle operates a stop fitting in notches at each end of the sector. The locking mechanism is connected with this latch, so that when the lever is locked, the latch handle cannot be moved to raise the stop, and consequently an attempt to pull a locked lever does not put any strain on the wire or rod

connections. To the ends of the horizontal arms of the lever are attached wires, chains or rods which run down to the lower floor of the tower and out to the roadbed. This forms the lead-out. Signals are usually operated by wire, though home signals are very generally operated by lines of pipe, which gives a more uniform and positive indication. Distant signals in some cases also have pipe connections. Where wire is used, there should be a double wire, so connected as to give a positive pull in both directions, and the arm is balanced by a counter-weight to return it to the "stop" position in case of a wire breaking. Pipe is used exclusively for switches, and both wire and pipe are used for locks. The pipe is usually 1-in. gas pipe, with screw or plug joints, but solid rods are used where the wire has to be bent or curved. It is supported at intervals by anti-friction roller carriers, while wire is carried on small pulleys attached to stakes. Changes of direction are made by means of bell-cranks (or rock shafts at the lead-out) for pipes, while for wire a length of chain is inserted and passes round a grooved pulley, 6 to 8 ins. diameter. In order to allow for contraction and expansion and for slack due to stretch of the wire, compensators are used to automatically adjust the length, or hand adjustments for wire may be used at the tower. The pipe compensator may be of the "lazy-jack" double bell-crank style, or a simple lever at right angles to the pipe line and pivoted at the middle, the pipe line being offset for the length of the lever. Wire compensators should give a rigid connection when the signal is pulled, so as to ensure that the signal will be operated. Hand adjusters are usually screw sleeves for wires or turnbuckles for pipe. In cities, the signal wires may be carried under streets, etc., in ½-in. or 1-in. pipes filled with crude oil, the pipes requiring to be refilled about twice a year. The foundations for pipe carriers, bell cranks, chain wheels, etc., should be of concrete, though wooden frames are more generally used. One lever is sometimes made to operate two or more locks, switches, etc., by means of a selector. This device connects the wire or pipe from the tower with the separate pipes or wires of the movements to be controlled. When the switch is set for a certain route, the selector connects the pipe from the cabin with the pipe leading to the signal for that switch, but locks all the other pipes. This practice has in some cases been carried to extremes, especially in enlarging small plants without enlarging the lever frames, with the result of overloading the levers and making the plant uneconomical in operation. The use of selectors is now in less favor, and the much better practice is to use separate levers, grouping them conveniently for the signalmen.

The signals are usually carried on wooden posts 10 x 10 ins., or on steel posts of tubes or built up of angles and lattice bars. Block signals are usually about 15 to 20 ft. above the track, but at interlocking points the height may be increased to 30 or 40 ft. On the Chicago, Milwaukee & St. Paul Ry. some of the steel bracket posts are 36 ft. high, carrying other posts 5 to 10 ft. high. Dwarf signals are commonly used for switching and reverse or back-up movements. The semaphore arm is set in a spectacle casting pivoted to the post, so made as to counterbalance the weight of the arm and having colored lenses, moving in front of the lamp.

The following are extracts from the standard specifications of the Signal Department of the Pennsylvania Lines:

Specifications for Signals; Pennsylvania Lines.

One lever may be used to throw one or more switches, locks, or detector bars, or one or more low-speed signals through a selector. In no case must one lever be used to throw (A) a switch and lock, (B) a switch and signal, (C) a lock and signal, (D) a home and distant signal, or (E) a high-speed and a low-speed signal.

Bell crank lead-outs must be used for pipe connections wherever possible. Where rocker shafts are used they must be of uniform size and not less than 2¼ ins. diameter.

Pipe lines must be used for connections to switches, detector bars, locks, selectors and block signals, and may be used for all signals. Pipe must be made of wrought iron, 1 in. inside diameter, painted inside and outside, and coupled with sleeves, plugs and rivets. Pipe lines must be straight when possible, and must be placed not less than 3 ft. from outside of rail, except for signals, where they may be placed on carriers clamped to the rail. They must be laid 2¾ ins. c. to c., and arranged so that the shortest line will be next to the rail. They must be supported on carriers placed 7 ft. apart; top of pipe lines must not be less than 1 in. below base of rail. Pipe carriers must be of cast iron, with sheaves not less than 2¼ ins. diameter. Couplings in pipe lines must be placed not nearer than 12 ins. to a pipe carrier when the lever is in the center. Sleeves for pipe couplings must be of wrought iron, and not less than 2¼ ins. long. Plugs for pipe couplings must be of wrought iron, 1 in. diameter and 6 ins. long. They must be drilled for ¼-in. rivets, spaced 4 ins. c. to c., and 1 in. from each end. Bends must not be made in pipe, but in cranks, jaws or a 1¼-in. iron rod placed in the pipe line for that purpose. They must not exceed 2½ ins. at any one point.

Bell-cranks must be of wrought iron, and mounted in a cast iron stand. The top of the center pin must in all cases be supported. No more than three bell-cranks may be placed on the same center; and in no case may two bell-cranks be placed on the same center or foundation when one pipe line runs to a switch, and the other to the lock on the same switch. Bell-cranks for semaphore switch signals must be adjustable, so that the stroke of the signal rod can be varied to suit the throw of the switch.

A compensator must be provided for every 700 ft. of pipe or fraction thereof, except in lines less than 100 ft. in length. They must be "lazy jacks" of wrought iron, and mounted on cast iron stands, but no more than one compensator may be placed on a stand or foundation. Crank arms must be 11 ins. c. to c. of pin holes. Top of crank pins must be supported.

Facing-point locks must be used in all switches. The lock casting must be placed on outside of track and bolted to the tie through an iron plate ⅜ × 6 ins., 8 ft. long, placed on the tie and securely fastened thereto through the rail braces. Plungers must be 1 in. diameter and 17 ins. long from c. of pin hole to end, and must be of full diameter on the end. They must have a stroke of 8 ins., and a hole must be cut in the tie to allow full stroke to be made. Plungers must stand not more than 1 in. clear of lock bar when the switch is unlocked. Lock bars must run straight from center of front rods into lock castings. Holes in lock bars must not be more than 1 1-32 ins. diameter, and not countersunk. Front rods must project beyond point of switch and be fitted with a special screw jaw on each end adjustable to 1-32 in. The connection between front rod and lock rod must be made by means of a jaw and lug on bottom side of front rod.

A detector bar must be provided for each route, working in connection with the facing-point lock, and must also be used at crossings when required to insure clearance. These bars must be of wrought iron, ⅜ × 2¼ ins., not less than 45 ft. in length, and square on end. They must be placed on outside of rail, and work in a plane inclined upward toward center of track, and top of bar must stand ⅜-in. below top of rail when the lock lever is at end of stroke. Supports for detector bars must be clamped to base of rail. Twelve supports must be used for each bar, 4 ft. c. to c., and 6 ins. from each end.

The driving piece must be placed midway between supports, and as near

the center of bar as practicable. Connection from pipe line to driving piece should be as nearly parallel to the track as possible; the crank end of connecting rod must be placed so as to stand not more than 8 ins. from outside of rail when the lever is on its center.

Means of adjustment must be provided for each line of pipe or wire, and all adjusting screws must be open. Pipe adjusting screws must be of wrought or malleable iron with right and left hand thread, and capable of giving an adjustment of not less than 6 ins. Wire adjusting screws must be of wrought iron, not less than ½-in. diameter, and capable of giving an adjustment of not less than 12 ins. Lines to switches must have standard adjustable center connection, with 1½ ins. more stroke than throw of switch, placed on center of head rod. Lines to derails must be provided with a pipe adjusting screw placed in end of line next to derail. Lines to locks, detector bars and counterbalance levers must have a screw jaw placed in end of line next to function operated. Wire lines to home signals must be provided with an adjusting screw placed in tower. Where the home signal is more than 400 ft. from the tower, an additional adjusting screw must be provided at the signal. Where wire bolt-locks are used, additional adjusting screws must be placed in the signal line on each side of the bolt lock. Each derail must be provided with a wire bolt-lock placed in the front wires to its home and distant signal. Where not otherwise specified, derails will be considered as switches, and must be provided for in the same manner. Both locks must have an independent connection to the switch points. The switch and signal bars must not be less than 1¾ ins. deep and ½-in. wide. The notch in the signal bar must not be more than 1½ ins. long, and that in the switch bar not more than 9-16-in. long. Bars must not be notched more than half their depth.

Signal arms may be carried on straight posts, bracket posts, or bridges. High signal arms must be of ash, and low signal arms of rubber. High signal posts must be of white pine, set in crossed frames, and braced thereto. Low signal posts must be of iron. High signals, where practicable, must not be closer than 7 ft. to outside of rail. Low signals must not stand closer than 3 ft. to outside of rail.

Ordinary posts must not be less than 7 ins. square where top center casting is attached, and 10 ins. square at the ground line; except for home semaphore switch signals, where they must be 8 ins. square at the bottom. Bracket posts must be made with a main post 12 ins. square, with two cross pieces of 3 x 12 ins. white oak for the bracket, and uprights 7 ins. square for carrying signals; all framed and braced. The bracket must not be less than 20 ft. above the top of rail. Short uprights or stubs 7 ft. long must be used to indicate each track that is not signaled from the bracket, and which intervenes between the bracket post and the farthest track signaled. These uprights must be not less than 7 ft. c. to c. On signal bridges, uprights 7 ins. square for carrying signals must be placed vertically over the right-hand rail of the track governed. Bridges must be not less than 21 ft. in the clear from top of rail.

Semaphore arms on the same high signal post must be placed 7 ft. c. to c., and the bottom arm on any high signal post for interlocking signals must be not less than 25 ft. above the top of rail, and for switch signals not less than 18 ft. Low signal arms must not be more than 2 ft. 6 ins. above base of rail. On bracket posts (or bridges) the bottom arm must be not less than 8 ft. above top of bracket or bridge; and where passenger and freight tracks are signaled from the same bracket (or bridge) the arms for passenger tracks must stand 7 ft. higher than the corresponding arms for freight tracks. High signal arms that stand less than 25 ft. above the rail must be 4 ft. 6 ins., and arms that stand 25 ft. or more above the rail must be 5 ft. 6 ins. from center of castings to outer end. They must all be 7 ins. wide at the arm grip; the first 10 ins. wide and the second 11 ins. wide at the outer end. Stops for danger and safety positions must be provided in center castings. The outer end of arms for home signals must be square with center line; for distant signals outer end must be notched to a depth of 8 ins. on center line, and at 30° with same. Corners of all outer ends must be rounded to a radius of 1 in.

All signals must be counterweighted so that the arm will go to the horizontal position should a break occur in any connection. Block signals and train-order signals must be counterweighted so that the arm will go to the horizontal position when the lever is released. Counterweights must incline downward at 45° to center line of arm when arm is horizontal.

Colored glass, 6½ ins. diameter for high signals and 5 ins. for low signals, must be placed in the signal casting. Where the lamp is on the side of the post the colored glass must be placed in center of counterweight. Where the lamp is on top of the post, the colored glass must be placed in center of the casting at end of arm grip. Where three positions are required, a spectacle frame must be used. Back-light castings must carry a blue glass 3 ins. diameter for high signals, and 2 ins. for low signals. They must incline downward at 45° to center line of arm when the arm is horizontal.

All block signals must be operated by pipe; other signals may be operated by pipe or wire. Wire for signals must be made of steel, No. 9 gage, and galvanized. Where signals are wire connected, both front and back wires must be used, and the back wire must have 1½ ins. more stroke than front wire. Where two or more signals are operated through a selector, one common back wire may be used for all. Where one back wire is used for two signals, it must be attached by a chain through a shackle running from one signal to the other. Where front and back wires are used, a counterbalance lever must be provided for each arm, and up and down rods to all signals must be so connected that the arm will be pushed to the clear position. Wire lines must be placed not less than 3 ft. from outside of rail. They must be carried on iron pulleys placed not more than 21 ft. c. to c., the sheaves of which must be not less than 2 ins. diameter. Turns in wire lines must be made around wheels with ¼-in. chain. Chain wheels must be of cast iron, not less than 6 ins. diameter, mounted in a cast iron frame, and not more than four in one frame. Wire eyes must be oval, not less than ⅝-in. diameter. Where split links are used, the points must be well hammered down. They must not be used for splicing chain on wheels. Wire carriers must be placed on stakes, except where they can be conveniently placed on pipe carrier foundations. Compensation must be provided for all wire lines over 600 ft. long.

A standard lamp must be furnished for each signal. For each stub on bracket posts a standard lamp with 5-in. plain blue front light, and a 2-in. plain blue back light, must be furnished. A standard lamp with a 5-in. plain red front light, and 2-in. plain blue back light, must be furnished for the fixed bottom arm on posts where there are no diverging routes to be governed by the lower arms.

All foundations must be made of white oak, dovetailed, braced and bolted. The joints of all foundations must be painted before being put together; the assembled foundations must be painted before being put into the ground. All foundations, except for carriers, must be set in concrete. The foundations must be as follows: For pipe carriers, 2½-in. oak, 8 ins. wide on top, not less than 24 ins. deep; for one way, they must be 12 ins. long, and increase 2¾ ins. for each additional way. For chain wheels, 2½-in. oak, 10 × 24 ins. on top, not less than 3 ft. 2 ins. deep. For dwarf signals, 2½-in. oak, 12 × 30 ins. on top, not less than 3 ft. 2 ins. deep except for new style, when top must be 10 × 58 ins. For bell-cranks, 4-in. oak, 10 × 24 ins. on top, not less than 3 ft. 2 ins. deep. For compensators, 4-in. oak, 12 × 48 ins. on top, not less than 3 ft. 2 ins. deep.

Stakes for wire carriers must be of oak, not less than 3 × 4 ins., 4 ft. long, with a 7-in. point. All pins must be made of steel, machine turned, and provided with cotters. Connecting pins for jaws, bell-cranks, etc., must be not less than ⅞ in. diameter; center pins for bell-cranks must be not less than 1¼ ins. diameter.

Home and distant signal arms must be painted yellow on the face, with a black band upon the arm, 1-10 of its length in width, and located 1-3 of the length of the arm from the outer end, the lines of which must be parallel with the outer end of the arm. The back must be painted white, with a similar black band across the arm.

CHAPTER 15.—STREET RAILWAY TRACK.

The great development of street railways due to the introduction of electric traction, not only for city and suburban service, but also for long-distance interurban and rural service, has been attended by very considerable improvements in track construction, and has opened a new field for engineers in the construction and maintenance of these lines. The term "street railway" does not properly apply to country lines, especially when built on their own right of way, and electric railway is not sufficiently distinctive. It would be much better to adopt the English term "tramway," comprehending all lines of this character. On lines outside of city and suburban streets, the character of construction is usually very similar to that of an ordinary railway, although if the line follows a highway it is paved over like the rest of the road. This is not necessary if the line is laid outside of the road, or upon its own right of way. In city streets the track construction is usually of a special character, adapted to the style of street construction, and greater permanence of surface is required than for ordinary steam railways, as the track must maintain its conformity to the surface of the street and there is no opportunity for the continual tamping, surfacing and tightening of bolts which is done on railway track. For this reason a substantial and permanent foundation is a necessity. The same paving material should be used across the entire width of the street, so as to distribute the traffic, but many railways lay a very inferior paving between the rails and tracks. Municipal authorities might well undertake the supervision of track construction and paving.

On many lines the street is simply surfaced to the subgrade for the paving, and has trenches cut below this for the ties, which simply rest on and are tamped with the natural earth. The rails are laid upon the ties, and the paving placed between them. This is a very poor system for city streets, as under heavy traffic the track very soon becomes rough and uneven and is very hard riding. In all cases the excavation for the track should be carried below the level of the bottom of the ties. The subgrade should be rolled, and then covered with slag, broken stone, or gravel, well rolled to a finished depth of 8 to 12 ins. below the ties. The same material (or concrete) should be filled in between the ties and form the foundation for the paving. In city streets, a concrete foundation for the tracks is most desirable, and with such construction the use of wooden ties may well be dispensed with, the rails being laid directly upon the concrete. Both of these systems are in use, but the tendency is to eliminate all wood in first class construction, the rails being connected at intervals by tie rods or tie bars through the webs, or by light steel ties embedded in the concrete and serving to maintain the gage. It has been contended that tracks having rails laid upon the concrete would be very rough riding and cause increased wear of wheels, bearings and cars, but actual experience does not sustain this objection, and there seems to be no reason why a good track operated by good rolling stock should give any trouble of this kind. In fact, some of the most easy riding track is built in this manner,

and on two parts of a line where the concrete base and the wooden cross tie system are both in use, no difference in the wear of rails or equipment has been found after careful investigation. Where a well-built track proves to be hard riding, attention may be directed to the car springs, as these have an important influence upon this matter as well as upon the wear of rails, and in many cases too little attention is paid to the design of the springs.

Where a country or suburban line is built on its own right of way or upon a road reservation apart from the highway proper, the ordinary system of track construction may be followed, using 60 to 80-lb. rails spiked to ties 18 to 30 ins. c. to c., laid on a suitable amount of ballast. Where the line is laid along a road, however, deep or girder rails are generally used. a 70-lb. 7-in. rail being frequently used, and connected by tie rods about 10 ft. apart. Where such a line is in a paved street, concrete may be rammed between the ties to form a foundation for brick or stone paving, or the concrete may also be laid over the ties to the necessary height for an asphalt paving. Where asphalt is used, or where a macadam road has heavy traffic, a line of bricks or granite blocks (laid as headers) may be placed to form or protect the grooves for the wheel flanges. On heavy grades, a similar plan may be used to prevent macadam paving from being washed out from along the rails, one or two lines of brick being laid as stretchers along the outside of the rail head. With an open track, the ordinary style of switches and frogs may be used, but where the rails are embedded in paving, the street railway type of tongue switch and grooved frog will be required. Many lines of this character (particularly interurban lines) are built specially for high speed, and have therefore their own private right of way, a width of 25 to 50 ft. being sufficient. They are usually single track with passing places, and ample signals and safety equipment should be provided, as the schedules are more variable and the discipline of the employees is less strict than on steam railways, so that there is greater liability of accidents. The block system of operation is sometimes established. Grade crossings of these electric lines with steam railways are too numerous, and should be efficiently protected, as noted in a previous chapter. In many cases they could and should be avoided, subways or viaducts being substituted.

The grades and curves may be considerably heavier than on ordinary railways, but for high speed electric interurban lines it seems probable that the curvature is in many cases excessive, and will have to be reduced to allow of safe and efficient operation. This will be realized when it is understood that speeds of 25 to 45 miles per hour are made on such lines. City lines have curves of 30 to 125 ft. radius, and sometimes the curves are transitioned. Curves of 400 ft. radius have transition curves 60 ft. long, with an initial radius of 3,400 ft.; 33-ft. curves have transition curves running out to 180 and 368 ft. at the ends. Curves of 75 to 150 ft. are used on suburban and country lines, but 300 to 350 ft. should be the minimum where high speeds are to be maintained. Terminal loops of 33 ft. radius have the gage widened ½-in., but no elevation is required as the speed is invariably slow. On curves up to 100 ft. radius, the gage may be widened ¼-in., but beyond that, standard gage is commonly used. The rules used for superelevation on steam railways do not give satisfactory results in these

cases, owing to the much lighter weight of the cars, but curves of 250 and 300 ft. radius on high speed lines, are sometimes elevated 3½ to 4 ins., using a guard rail on the inside. In city streets, an elevation of 2 ins. can sometimes be obtained on sharp curves without undue interference with the paving, but curves at intersections can have little or no elevation. In Boston, the rail is elevated for a speed of 15 miles per hour, where the street construction will permit of using the formula $E = (G\ V^2) \div (32.2\ R)$.

It must be borne in mind that the width of tread of wheels for electric cars is much less than that of ordinary railway wheels, so that very little widening of gage can be made without unduly reducing the bearing of the wheel upon the inner rail. On sharp curves where guard rails are required (sometimes all under 500 ft. radius), the gage may be widened a sufficient amount (according to the width of the groove) to prevent the flange of the wheel from cutting into the tread of the outer rail. Some double-track electric cars have trucks 17 ft. 9 ins. c. to c.; truck wheelbase, 4 ft. 6 ins.; wheels, 33 ins.; width of tread, 2¼ ins.; flanges, ⅞-in. deep and 1 in. thick; axles, 4½ ins. diameter. As to the grades, electric railways operate successfully on grades of 8 to 12%, while 5 to 6% grades are common. On cable lines, grades of 15 and 18% are surmounted.

As already noted, the rails may be laid either upon a continuous sheet of concrete across the street, or upon concrete stringers, the latter being

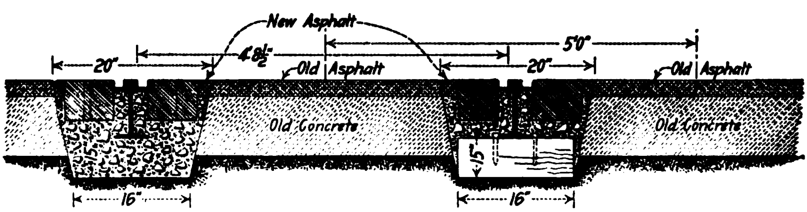


Fig. 191.—Street Railway Track; Kansas City, Mo.

specially economical in streets having either no concrete foundation, or one too thin to carry the track. Fig. 191 shows the arrangement employed by the Metropolitan Ry., of Kansas City. A trench is dug for each line of rails, 20 ins. wide at top and 16 ins. at the bottom, which is 6 ins. below the level of the rail base. Wooden blocks, 8 × 10 × 16 ins., are placed in the trenches, 10 ft. apart, the rails being spiked to the blocks and temporarily spliced. The track is then adjusted to line, gage and surface, after which the trenches are filled with concrete, tamped well under the rails to give them a full bearing, and allowed to set for about six days, according to the weather, as it will set more quickly in warm than in cold weather. The concrete is composed of 1 part Portland cement (by measure), 1 part natural cement, 4 parts sand and 10 parts crushed stone. It is put around the rails before the cast-weld joints are made, in order to protect the rails from the effects of changes of temperature. In constructing this system on existing lines, sections of about 1,000 ft. of one track are given up, portable crossovers connecting the tracks at the ends of each section. A somewhat similar system is employed at Buffalo, but the rails are temporarily laid on ties instead of blocks. The 9-in. girder rails, 60 ft. long, are drilled for tie-rods 10 ft. apart and for one bolt at each end for temporary splicing.

Oak ties, 5 x 7 ins., 7 ft. long, are laid 5 ft. apart, alternate ties being tamped with stone ballast, after which the track is surfaced, gaged and lined. The alternate ties are then embedded in concrete, well tamped, and a concrete stringer 8 x 15 ins. formed under each rail. For block paving, all the space between the ties and for 2 ft. outside the rails is also filled with a 6-in. bed of concrete, composed of 1 part Portland cement, 3 parts sand and 5 parts broken stone. This is allowed to set for 72 hours. The splice bars are then removed and the joints electrically welded. Under this system 2,500 ft. of track could be laid in a day. On other lines, concrete stringers were

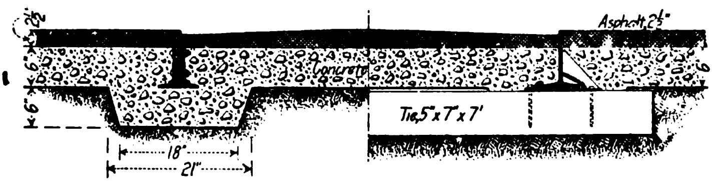


Fig. 192.—Street Railway Track; Indianapolis, Ind.

formed and allowed to set, and the rails then laid on steel ties on the stringers, the space between the stringer and rail being filled with grouting. This does not maintain as good line or surface, and only 500 ft. per day could be laid. The combination tie and stringer system, used at Indianapolis, is shown in Fig. 192. Wooden ties are laid 6 ft. apart, with brace plates on each tie. Between the ties is a 6-in. bed of concrete, embedding the rails and forming a foundation for the asphalt paving, while the depth is increased to form stringers 6 ins. deep under the rails. The use of brace plates on every tie makes it unnecessary to employ tie-rods, but in some cases timber is dispensed with and the rails are bolted to steel ties. Where wooden ties are used, as above described, they are sometimes removed when the concrete stringers are hard, and the trenches thus left are filled with concrete.

In the construction adopted at Toronto, and shown in Fig. 193, the entire width of the street is given a concrete foundation 6 ins. thick, increased

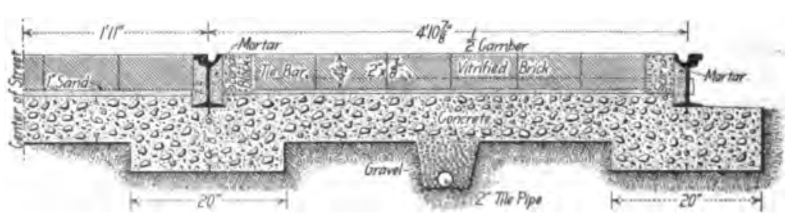


Fig. 193.—Street Railway Track; Toronto, Canada.

to 8 ins. for a width of 20 ins. under each rail, a groove 1 in. deep being formed in the concrete to receive the rail base, which is laid directly upon the concrete. Grooved girder rails are used, 6½ ins. high, with a line of scoria paving blocks laid along the inside of each rail, the rest of the paving being of 4¼-in. vitrified brick on 1 in. of sand. Mortar is packed between the rail and the paving, but tile blocks are sometimes used for this purpose. Tie-bars ⅜ x 2 ins. are set 6 ft. apart, the threaded ends passing

through the webs of the rails and being held by nuts on each side. In several cases old rails are used as ties. At Rochester, trenches 12 to 16 ins. wide are made, and the bottom covered with 4 ins. of coarse broken stone. A concrete foundation is then laid, 6 ins. thick, increased to 10 ins. at the ties, and to 17 ins. for a width of 12 to 16 ins. under the rails. The top of the concrete is ½-in. above the base of the rail. The rails are of 6-in. 86-lb. grooved girder section, with ties of old inverted girder rails 6 ft. apart. On double track, every joint tie and every third tie is 16 ft. long, holding all the rails.

Where wooden ties are used, they are usually of sawed pine, oak, cedar, chestnut or hackmatack, 6 × 7 ins. to 6 × 10 ins., and 7 to 8½ ft. long, though a few roads use 6-ft. ties, which are not to be recommended. They are spaced 18 to 30 ins. c. to c., except that where they are used mainly to hold the rails during construction they may be 5 to 10 ft. apart. Where the concrete floor system is employed, the rails are often attached to light steel ties or 3-in. angle irons, which serve to maintain the gage and are embedded in the concrete, 5 to 10 ft. apart. With high rails, however, it is very common practice to connect them by 1-in. tie-rods (if to be embedded in concrete) or tie-bars (if to fit between courses of paving blocks), which pass through the webs and have nuts on each side of the web. With wooden ties, ordinary spikes are used and steel tie-plates; combination tie-plates and rail braces being used on every tie or on a certain proportion of the ties. These are sometimes supplemented by tie-rods at the joints. The rods and braces are to maintain the gage and resist the lateral thrust due to street traffic.

Girder rails and ordinary T rails are now almost universally used, the various forms of strap, box and compound rails, and shallow rails supported on chairs, being practically obsolete. Girder rails are used for lines of all classes, but more especially for streets, while T rails are used mainly for suburban and country lines. The girder rails have heads of the center-bearing, side-bearing or grooved patterns, as shown in Figs. 191, 192 and 193. The first of these is most objectionable and should not be allowed by the municipal authorities, as it makes a rough riding street surface and forms two extra and entirely unnecessary grooves to each track. With the side-bearing head there is no groove proper, but the entire width of paving between the rails of each track is lower than that of the rest of the street. This makes an irregular surface, inconvenient for driving and difficult to keep clean. For city streets, the grooved head is the best, the rail head being wide enough for the widest wagon wheels and having a groove for the car-wheel flanges, these grooves being the only break in the contour of the street. The inner side of the groove is nearly vertical, but the outer side may be flaring or vertical. The New York rail has a groove 1⅛ ins. deep and 1¾ ins. wide on top, while the Washington and Cincinnati rails have grooves about 1 1-16 ins. wide and deep. The latter gives the least break in the pavement, but the former enables narrow wheels to turn out easily and is also more easily kept clean. The dirt, snow, etc., in the groove offers some additional resistance to traction, but the general advantages of this form of rail far outweigh any minor objections on the part of the railway companies. When first introduced, following long established English practice, it was claimed that narrow tires would be caught and

that the grooves would be so clogged up with street dirt that cars would not be able to run. Practical experience has shown that the use of these rails is entirely practicable and very advantageous. Girder rails are 6 to 10½ ins. high, and weigh from 70 to 120 lbs. per yd.

The use of T-girder rails, resembling high and narrow railway rails, is now quite general, mainly for lines in the smaller towns and on country roads. Brick or block paving may be laid to leave a flangeway, not exceeding 1⅛ ins., the space being filled with fine concrete, covered with asphalt to the level of the required depth of groove. Special blocks may also be used, having chamfered ends to fit under the rail head and form the flangeway. At Minneapolis, 80-lb., 60-ft. rails of the Am. Soc. C. E. section are used (5 ins. high and wide), being laid on concrete stringers 8½ × 15 ins. and connected by tie-bars 10 ft. apart. The asphalt pavement is 2½ ins. thick, on a 6-in. concrete foundation, with a line of granite blocks inside each rail, leaving a flangeway of 1¼ ins. This is filled with concrete and asphalt, the groove being formed by the car wheels.

The rail joints may be spliced the same way as those of steam railways, but for very tall rails the splice bars are usually of channel section, with double row of bolts, and have sometimes a horizontal rib which bears against the web of the rail, as shown in Fig. 192. Many of the special joints described in a former chapter have also been adapted to street railway track. Within recent years, however, the elimination of the joints by welding the rails together has been very extensively practised, and in general with good results. As the rails are embedded in the paving, and only the top of the head is exposed, the contraction and expansion due to temperature are very much reduced, and where breaks occur they are more often due to faulty welding than to the contraction of the rails. On electric trolley lines, where the rails are used to carry the return current, the joints must be bonded or connected by copper wires or plates, so that the current will flow uninterruptedly from rail to rail and not seek an easier path through the earth owing to the resistance which it encounters in passing the joints. In practice, however, this bonding is very defective, the conductivity of the bonds being far less than that of the rails, with the result that the current escapes and travels along water and gas pipes and other conductors, causing electrolytic corrosion or electrolysis. It is generally claimed that welded joints eliminate the necessity of bonding, the continuous rail offering no resistance, but while this may be the case with new or specially well made joints it does not hold good in general. Careful tests made in investigations as to electrolysis show a very material increase in the resistance, or loss of conductivity at the weld.

The joints may be welded electrically or by pouring melted iron around the rail ends. In electric welding, as now practised, steel bars about 1 × 3 × 15 ins. are clamped to the rail webs, and three electric welds are made at the rail ends and the ends of the bars, heavy pressure being applied while the rails are heated by an electric current. In the "cast-weld" system, a hinged mold is clamped to the joint, and a vertical screw applies pressure from above to keep the rail ends from buckling vertically under the influence of the heat. Metal heated to a white heat in a portable cupola is then poured into the mold, which is left for about an hour. The metal is usually composed of about 67% pig iron and 33% scrap, and the best

results are obtained where a thin iron shim or plate is inserted at the joint. The rail ends must be clean and bright to ensure good work, and the joint should be ground or dressed to a plane surface. Breaks are classed as broken rails, broken joints and slipped joints, the latter being due to imperfect welding. They may be repaired by re-welding, putting on splice bars, or by cutting out 10 ft. of rail and putting in a new piece with two joints. Reinforced joints are used with 5-in. and 6-in. rails at Scranton, Pa. Ordinary angle bars are bolted to the rails with six bolts, and an inverted piece of rail 4 ft. long is rived to the base of the rails with 18 rivets, four of these being of copper to act as electric bonds. A pneumatic riveter is used, suspended from a derrick on a construction car. As the work on rail joints represents some 75% of the general track maintenance, and as this work is done under unfavorable conditions, the desirability of eliminating joints may readily be seen. For this reason 60-ft. street rails are very commonly used.

In paved streets, the switches are usually of the tongue pattern, a pivoted tapering tongue moving in a casting having a wide groove. The switch or tongue is placed on one side of the track only, a fixed point or "mate," like a frog point, being placed on the opposite side. Frogs and crossings are usually steel castings, manganese steel and other specially hard makes of steel being often inserted at the points of most severe wear. Passing sidings may be arranged in different ways: (1) The main track continued in a straight line, with the siding on one side; (2) Both tracks diverted equally from the center line; (3) The main track offset so as to overlap for the length of the siding. In the third case, the automatic spring switches are set normally for the straight line, cars in each direction having a facing switch always open, and trailing through a closed switch after passing through the siding. For turnouts, junctions, grade crossings, etc., very complicated special work is often required, and these parts are built up in a very solid and substantial way. Guard rails are required on sharp curves, and these may be grooved girder rails with wide grooves and guards of exceptional thickness. For T rails, a heavy rectangular bar may be used, bolted to the web of the track rail, with spacing blocks of the required width. Special care must be taken in laying out curves to ensure easy riding and (on double track) to prevent any liability of cars striking when passing on a curve. On some very sharp curves it is impossible to spread the curves to prevent this interference, and cars must not attempt to pass each other on the curve. Transition or spiral curves are now very generally adopted, not only for ordinary curves on outlying parts of the line where cars run at high rates of speed, but also on sharp city curves, to eliminate the severe shock and swing caused by a car passing from the tangent to the curve. Where very heavy grades are encountered, a balance system may be used, in which a heavily loaded truck running down in a conduit helps to haul a car up the grade, a descending car then pulling the counterweight truck up again. The electrical equipment does not come within the scope of the work, but some notes may be given as to the poles. These are usually about 30 ft. long (40 to 50 ft. crossings), set 6 ft. on the ground. Those at the side of the track are inclined slightly outward to resist the pull of the span wires which carry the trolley wire. A back board spiked against the pole below the level of the ground, and a filling of con-

crete or stone behind the pole, will add to its stability. Wooden poles are about 5 or 6 ins. diameter at the top and 10 to 11 ins. at the butt, and may be of cedar if left round, or chestnut if trimmed to a square or hexagonal section. Iron poles may be tubular or built-up, the former being the most common and usually consisting of three tubes 5, 6 and 7 ins. diameter, with telescoped and swaged joints.

In regard to the maintenance work, this is now very generally in the hands of a department organized somewhat on the same lines as that of a steam railway. The Union Traction Co., of Philadelphia, Pa., has a roadway department in charge of track, roadbed, paving, conduits for electric cables, bridges, and repairs to buildings. This is in charge of an engineer. The regular maintenance gangs are assigned monthly to a certain district, and besides the general repair work the entire track and paving is gone over about once a year for surfacing, repairing joints, etc. Such work as oiling guard rails on curves, sanding tracks on steep grades and cleaning switches is done by men specially detailed for the purpose, each man doing the work in a certain district. The engineer reports monthly to the president and general manager, stating the work done and the supplies on hand, and giving an estimate of the work proposed for the next month. The Chicago City Ry. has a trackmaster in charge of the entire system, which is divided into six sections of about 40 miles, each in charge of a section foreman. One of the men on each section is detailed as a caller, and in case of emergency, accident, snowstorm, etc., the telephone operator calls up this man, who then notifies the rest of the gang and tells them where they are to go.

PART II. TRACK WORK.

CHAPTER 16.—ORGANIZATION OF THE MAINTENANCE OF WAY DEPARTMENT.

One of the most important points in regard to the efficient and economical operation of a railway or a department is the system of organization adopted. In the organization of railway operating service there are two distinct systems: (1) The division system; (2) The department system. Under the first of these, each division is operated practically as an independent line, its superintendent having control of transportation, maintenance of way, and maintenance of equipment. All other officers on the division report to him, and he reports to the heads of the several branches of the service. The latter transmit all instructions to him, which he refers to the proper subordinate officers. Under the second system, the several branches of the service (for the line as a whole) are centered in the heads of certain departments, which are usually as follows: (A) The engineering department, in charge of the construction and maintenance of line, roadway and appurtenances; (B) The mechanical department, in charge of locomotives, cars, machinery, floating plant, shops, etc.; (C) The operating department, in charge of train service and traffic. Thus the division engineer reports to the chief engineer, the division master-mechanic to the superintendent of motive power, and the division superintendent to the general superintendent. The first system is in many ways the better, as in this way all authority and responsibility for the work of each division are centered in one man, which arrangement conduces to the economy and efficiency of the service. The maintenance-of-way forces may be organized to be in one of three different relations to the general organization: (1) As a separate department; (2) As a division of the engineering department; (3) As a division of the operating department. The first is only practicable on very large railway systems, and of the two others, the former is the more appropriate and advantageous. The bridge and building forces and the signal forces should be organized as divisions of the engineering or the maintenance department, and the signal division should include train-order and switch signals as well as block and interlocking signals. On a very large railway having the maintenance-of-way work under the engineering department it would be impossible for the chief engineer to attend personally to details of track work, as well as to

all the other varied work of his department, and thus there is often an engineer of maintenance of way or a general roadmaster to act in the place of the chief engineer for all ordinary matters. On a smaller road, however, the chief engineer may well be in direct touch with the roadmaster. It is well to have as little subdivision of authority as possible, but the extent of such subdivision will necessarily depend largely upon the mileage and traffic of the road. The systems of organization in force on some leading railways are given below in detail, classified according to the three systems above noted.

(1) Maintenance of Way as a Separate Department.

Pennsylvania Ry.—The engineer of maintenance of way and the chief engineer are separate officers, reporting to the general manager and the second vice-president respectively. The former is one of the three "cabinet officers" assisting the general manager (engineer of maintenance-of-way, general superintendent of transportation, and general superintendent of motive power). He is represented on each of the grand divisions by a principal assistant engineer, who in turn is represented on each of the operating divisions by an assistant engineer, to whom the supervisors report. The supervisors (who answer to roadmasters on other roads) are educated engineers, in charge of about 25 miles of line, and have each an assistant. Subordinate to them are the track foremen, whose sections are 2½ miles long on double track, and four-track lines. The maintenance of way department has general charge of the road, including track, bridges, buildings, turntables, water supply, signals, etc., after the same have been completed for operation or use. On each division there is a master carpenter, who looks after general repairs to bridges, buildings, etc., and there are also masons to do repair work.

Southern Pacific Ry.—There are two engineers of maintenance of way, one for each of the two systems into which the road is divided. Each reports to the general manager of the road, on matters relating to standard plans and methods, and to the manager of his own system in all other matters. The chief engineer has to do only with the construction of new lines and with important changes on existing lines. The engineer of maintenance of way acts as assistant to the manager, and he has immediate supervision of all matters pertaining to the maintenance or renewal of the roadbed, track, bridges, buildings, etc., and also has direction of all construction work. He prepares the pay rolls and keeps the accounts of the department, the accounts being rendered to the auditor at the close of each month. He has under him a superintendent of bridges and buildings, a signal engineer, an assistant engineer, and division engineers, the latter assisting the division superintendents in all matters pertaining to the maintenance of the track. On one of the two systems of the road, the section foremen and foremen of bridges and buildings report to the roadmasters, who report to the division engineers. The other system has no division engineers, the bridge and building foremen reporting to the superintendent of bridges and buildings, and the roadmasters to the division superintendents. The department includes track, bridges, buildings, water supply, turntables, coaling stations, and all classes of signals.

(2) Maintenance of Way Subordinate to the Engineering Department.

Illinois Central Ry.—The engineering department looks after construction work and the maintenance of the entire fixed property, including track, bridges, buildings, turntables, water supply, interlocking and block signals, etc. Section men report to supervisors, who have charge of about 100 miles of track; and these report to roadmasters, who have charge of divisions from 250 to 500 miles in length. The shorter division is 63 miles (near Chicago), and the longest is 518 miles (along the Mississippi River). The roadmasters report to the division superintendents, who in turn report to the two assistant general superintendents (one north and one south of the Ohio River). These report to the chief engineer upon all matters relating to the physical condition of the property and to the general superintendent upon matters relating to transportation. The latter officers report to the second vice-president. The chief engineer has under him a signal engineer and an engineer of bridges and buildings; the latter of whom has under him a superintendent of bridges, a master carpenter and an architect. The two former look after special construction and renewal, the ordinary maintenance of the bridges and buildings being in the hands of the roadmasters. Painters are employed as required by the roadmaster, master carpenter and superintendent of bridges. On main line, with single track and gravel ballast, an ordinary section gang consists of a foreman and 6 men to a section 6 miles long, one of these men usually acting as trackwalker. This force is reduced on the less important main lines with gravel ballast to a foreman and 4 men, additional men being employed as needed to put in extra ballast, lay new rails and do other important work which cannot be taken care of by the regular gang. With earth ballast (which is used only on unimportant branch lines) an ordinary gang consists of a foreman and 3 or 4 men, but such a gang is increased when it is necessary to do any extensive ditching, general surfacing, etc. There are several hundred miles of track with stone ballast, and for this the section gangs are composed of a foreman and 6 men to a section 6 miles long, additional gangs being employed for extra work in ballasting, laying rails, etc. The average force allowed is 1 man per mile in summer, and 1 man per 2 miles in winter.

Michigan Central Ry.—The chief engineer has charge of all construction, and of the maintenance of track, bridges, buildings, water supply, real estate, interlocking, and signals of all kinds. The division roadmasters report direct to the superintendent of tracks, who reports to the chief engineer. The general scheme of organization is as follows:

Officers.	Reporting to	Officers.	Reporting to
Prin. Asst. Engr.	Chief Engineer.	Foreman of Repairs	Asst. Roadmasters.
Bridge Engineer	" "	Div. Foremen of Bldgs. and W. S.	Supt. Bldgs & W. S.
Signal Engineer	" "	Masons and Bdg. Carps.	Div. F., B. & W. S.
Supt. of Tracks	" "	Carps. and Painters	" "
Supt. of Bldgs & W. S.	" "	Asst. Bridge Engrs.	Bridge Engineer.
Assistant Engineers	Prin. Asst. Engr.	Div. Foreman of Bdgs.	" "
Roadmasters	Supt. of Tracks.	Signal Inspectors	Signal Engineer.
Assistant Roadmasters	Roadmasters.		

New York Central Ry.—The track work is under the engineering department, in accordance with the following section of the company's by-laws: "The chief engineer, under the direction and supervision of the third vice-

president, shall have the care and charge of the roadbed and tracks, and all buildings and structures appertaining thereto; docks, piers, bulkheads, sheds and warehouses. Ordinary maintenance of the roadbed, track and structures shall be under the charge of the general roadmaster, in accordance with standard rules, regulations and plans prepared by the chief engineer, under his supervision and control." The third vice-president is the executive head of the operating department. The engineering department has charge of all construction and maintenance, including track, water supply, turntables, and switch signals. The block signals, however, are under the operating department, each division superintendent having an assistant superintendent of signals, but it would seem very much better to have all signals under one head, and that under the engineering department. The general scheme of organization is as follows:

Chiefs.	Subordinates.
Chief Engineer..........	Division engineers (7).
Division Engineers......	Roadmasters, supervisors of buildings and water supply, assistant engineers, supervisors of bridges.
Roadmasters............	Section foreman and gangs, ballast and special gangs, pumpers.
Engineer of Bridges.....	Iron bridgemen, masons, pile-driver gangs, bridge painters and carpenters.
Supervisor of Buildings..	Carpenters, painters, water supply and scales men.

(3) Maintenance of Way Subordinate to the Operating Department.

Atchison, Topeka & Santa Fe Ry.—All such work as new construction, reconstruction, changes in line, replacing bridges by permanent work, establishing new buildings and water stations, etc., is under the authority of the chief engineer. The maintenance-of-way work, ballasting, repairs to track, timber trestles, care of bridges and buildings and maintenance of signals, are all under the direction of the general superintendent. The jurisdiction of the signal engineer includes block and interlocking signals and semaphore train-order signals, but does not include the switch signals or the old target train-order signals, which are attended to by the maintenance of way forces and the bridge and building forces respectively. It would be better, however, to concentrate the responsibility in regard to signals. All switch signal and train-order lamps are under the supervision of an inspector who reports to the signal engineer. The track foremen report to the roadmasters, who report to the division superintendents, who in turn report to the general superintendent. On each division there is a general foreman of bridges and buildings, who reports to the division superintendent, and who has charge of the maintenance and repairs of trestles, building and water service. The carpenters and painters report to this general foreman. The roadmasters' divisions average 140 to 150 miles. The shortest is 106 miles, all main track; the longest is 250 miles, nearly all branches.

Erie Ry.—The organization of this road is entirely on the division system. The chief engineer has charge of all construction work, and of bridges and buildings. Indirectly, he also has charge of maintenance of way, as he establishes all standards relating to track and signals, and these cannot be changed without his consent. The engineer of maintenance-of-way has charge of all matters pertaining to maintenance of track, bridges, buildings, water supply, etc. All the division engineers report to

him on these matters, and he reports directly to the general superintendent. Plans for all new work and important structures are prepared by the chief engineer, who either assumes direct charge of construction, or refers it to the engineer of maintenance of way, and thus to the division superintendents, who in turn refer it to the proper officers. On the Erie Division, each division superintendent has a roadmaster, who has an assistant engineer and a rodman under him. On the Ohio Division, the roadmaster and assistant engineers are combined, and have the latter title. The roadmaster (or assistant engineer) has under him supervisors, track foremen, carpenters, masons, and all the mechanics and laborers necessary for the maintenance of way.

New York, New Haven & Hartford Ry.—While the maintenance of way is under the operating department, the engineering department is consulted on all important work. The chief engineer has under him a bridge engineer and two district engineers. He has supervisory authority as to all changes and renewals of roadway, bridges, buildings and docks. The roadmaster, supervisor and signal engineer of each division report to the division superintendent, who reports to the general superintendent. The supervisor has charge of bridges, turntables, and coal and water stations. Signal inspectors and repair men report to the signal engineer. Carpenters, masons and painters report to the superintendent of buildings, who reports directly to the general manager. The length of roadmasters' divisions on double track is from 50 to 75 miles, with various lengths (up to 50 miles) of single track in addition. The New York division includes 55 miles of four-track, 17.25 miles of double track, and 7.66 miles of single track. The length of sections is 2 miles on four-track or 4 miles on double track. The number of men (including foremen) in the section gangs on important lines is 9 in spring (with full force) and 5 in winter. On less important lines, 7 and 5 men; and on unimportant side lines, 6 and 3 men respectively.

Whatever may be the system of organization of the department, the system of organization of the working forces is almost invariably uniform for all roads. The line is divided into sections, the work on each of which is in charge of a section foreman and section gang. The length of sections varies according to the number of tracks, character of construction, number of yards and switches, and the amount of traffic. The average is about 5 to 7 miles on single track, and 3 to 5 miles on double track; 3½ to 4 miles of double track being equivalent to 5 miles of single track. On four-track lines, the length of sections is from 2 to 3 miles. The amount of work does not increase directly in proportion to the number of tracks, as ditching, clearing right of way, cutting grass, etc., average about the same in any case, the greater amount of clearing on a single track right of way compensating for the greater care usually required on double track. On double track, however, the men know in which direction to look for trains, and can therefore do their work and run their hand-car to better advantage and with greater safety. The number of frogs and switches has a material influence on the amount of work, and the number of men allotted to the section, as noted later. Table No. 16 shows the organization and the distribution of labor on some leading railways:

TABLE NO. 16.—ORGANIZATION FOR MAINTENANCE-OF-WAY.

Railway.	Length of— Roadmaster's divisions, miles.	Length of— Track sections, miles.	No. of tracks.	No. of men in section gang. Spring.	No. of men in section gang. Winter.
Atch., Top. & S. Fe.........	140 to 150	8	1	5 to 7*	3*
Balt. & Ohio.............	40 to 65 d. t.	4	2	6 " 12*	2 to 8*
	65 to 130 s. t.	5 to 8	1		
	50 of double track				
Boston & Albany.........	with at least 20 of	7	1	10	4
	single trk brnchs.	4	2		
	115 of d. t. main				
Boston & Maine	line and about 115	3	2	6 to 9	3
	of s. t. branches.	4 to 5	1	5	3
Chicago & Northwestern..	....	4	2	..	..
	....	6	1	7	3
	80 to 100 on main				
Chic., Burl. & Quincy.....	line, plus 60 to 80	2½ to 5	1	4 to 7	2 to 4
	of branches.	5 to 6	2	..	..
Chic., Mil. & St. Paul......	100 main track.	4 to 5½	1	3 to 7	2
		3 to 3½	2		
Clev., Cin., Chic. & St. Louis	80 to 150	5	1		
		3	2	6*	3 to 4*
Erie	100 to 140	6 to 7	1	..	..
		5	2	8*	5*
		6	1	0.5 to 1.1	
Illinois Central	Average, 300	4	2	per	..
		8	Brnchs.	mile.	
Lake Shore & Mich. South'n	100	5	1	10	4
		3½ to 4½	2	..	..
Michigan Central	....	5	1	4*	3*
		4	2	..	..
New York Central	40 to 50	4	2	3 to 4	..
	25 to 35	3	4	6	..
	36 to 148	4 to 7	1	..	..
N. Y., N. H. & Hartford...	50 to 125	4	2	8	4
	N. Y. Division, 55.	2	4	9	5
Northern Pacific	100 to 150	6 to 10	1	Ave., 3.	..
Pennsylvania	25	2½	2 and 4	5 to 9	..
Wabash	83 to 260	6	1	6½	3

*Including foremen.

A new system of organization for track forces has been introduced on the Ohio River Ry. by Mr. C. E. Bryan, the Superintendent of Maintenance of Way and Structures. On each division there is a supervisor in charge of all the forces, and the sections have been changed from 7 to 8 miles, and the gangs reduced from a foreman and 6 men to a foreman and 3 men. The divisions are also divided into 30-mile sections, each with a floating gang consisting of a foreman, 20 men and a cook. The gang has a camp train of four box cars and a flat car for boarding and sleeping accommodation and supplies. The small section gangs go over their sections daily (the trackwalker being done away with); they inspect the track, make small repairs to track and fences, keep station grounds neat, etc. The larger gangs do such work as ballasting, renewing ties and rails, widening banks, ditching, etc. It is contended that the daily inspection will be better, as it is under the eye of the foreman and repairs can be made at once. Under this system, the work of replacing 56-lb. with 75-lb. rails, re-ballasting and re-tieing was carried on the spring of 1900, without any increase in forces, while under the ordinary system a tracklaying force and a ballasting force would have been required. Rails, ties, ballast, etc., are distributed to the divisions, each of which is able to do all this work on about 8 to 10 miles per month.

Roadmasters.

The position and responsibility of the roadmaster vary on different roads. In some cases he is at the head of his department, and in others

he occupies a more subordinate position. He is the direct head of the track work on his road or division, being the intermediary between the executive officers and the working forces. He should therefore be an intelligent and educated man, and should cultivate a spirit of good feeling between himself and his men, so that they will feel he is friendly and just to their interests and in his dealings with them. It has been shown in the introductory chapter that there is now a more general recognition of the fact that engineering knowledge and experience are essential in track maintenance work, and that a roadmaster on an important road should be something more than a high grade of section foreman. There is at the present time a marked tendency toward the development of the organization of the roadway department upon an engineering basis. The average cost of labor and material for track maintenance is from $600 to $1,000 per mile per year, which is 17 to 25% of the operating expenses and 10 to 17% of the total expenditures. On a roadmaster's division of 100 miles, therefore, the annual expenditure may amount to $60,000 or $100,000. It will be evident, then, that the roadmaster should be a man capable of controlling the expenditures wisely and economically. The title of roadmaster is not very significant, and superintendent of track, inspector of track, or engineer of maintenance of way would be much more appropriate.

As to the question whether the roadmaster should be an engineer, or what is vaguely termed a "practical man" (meaning one promoted from the ranks of the section foremen), a very little consideration will make it evident that the former is by far the best-fitted for the duties and responsibilities of the position. Besides the general work of maintaining the track in good condition, the roadmaster should be familiar with the principles of curve and switch work and yard design, the problems connected with ties and tie preservation, the relation of rail sections and weights to wear of wheels and rails, and other matters of similar character. All this, of course, is part of the engineer's training, and he is also familiar with the instrument and mathematical work. He must, however, understand the limits to mathematical precision in track work, so that he will not figure out his turnout leads to decimal points, when a little variation may avoid the cutting of a rail and will make no difference in the turnout; in the same way he must understand the limitations which traffic conditions impose upon superelevation, gage on curves, etc. He must also be thoroughly familiar with the practical details of track work, or his subordinates and the laborers will have little respect for him. But while he must know enough of his men's work and the use of their tools to be able to direct and govern them, there is no necessity of his being an expert with the spiking maul or the tamping bar, any more than the general manager need be an expert at the typewriter, or the mechanical superintendent an expert at firing an engine. The opponents of the system of putting the track work directly in the hands of engineers usually regard the engineer as being mainly a surveyor and draftsman unaccustomed to "practical" work or the handling of men. This is a very erroneous idea, however, as the engineer is a man of liberal training and generally of wide experience. In charge of such work as construction, reconstruction, changing grade and alinement, bridge renewals, etc., he has to organize his forces, to handle and direct large bodies of men, and to provide for carry-

ing on the work with rapidity, economy and the least interference with traffic.

The roadmaster who is a "practical man," a sort of first class foreman, is probably thoroughly competent in all track work proper, but is apt to be contemptuous of instrument work and mathematical calculations, because he does not understand them or their purpose. The niceties of superelevation and of easement curves are beyond him, and he does not like to see an engineer set stakes for his guidance. He will rely upon getting his switches in and making his curves easy riding by means of his eye, rough measurements and "trial and error." He is not competent to comprehend the economic principles underlying his work, and is also liable to prove inefficient in the handling of men. It has been pointed out by Mr. B. Reece, in a paper on "Railway Track Repairs" (Transactions of the American Society of Civil Engineers, 1884), that the "practical" man is apt to rely more upon special rules and instructions and personal direction, than upon general rules and written orders. The latter, however, is the better plan in directing large bodies of men, leaving the former practice to the subordinate officers. Besides this, the education of the section foreman is usually too limited to fit him for higher responsibility; while his lack of knowledge of operating conditions and railway economics makes it hard for him to understand how and when it is best to expend labor and money. In the past, many excellent roadmasters have graduated from the ranks of the section foreman, but a more special and technical training is required to meet the conditions of modern railway maintenance.

Great difficulty is often experienced, however, in obtaining men who combine practical and technical training with ability to command, and the railways are beginning to look to the engineering colleges to supply men of education whom they can educate in the service. On the Illinois Central Ry., half of the roadmasters are engineers, and this proportion is increasing. Under a system of track apprenticeship adopted under the direction of Mr. John F. Wallace, Assistant Second Vice-President, graduates from engineering schools are given work with the section gangs for a year or two, and then promoted to be foremen, supervisors and ultimately roadmasters. Other roads have adopted a somewhat similar plan, but less systematically and on a smaller scale. It must be recognized, however, that the training these young men have received, while perhaps of little immediate value to the railway, is a good foundation for future development, and that therefore they should be given some encouragement and promise of promotion. Otherwise they will naturally not care to enter the roadway service, with small pay, hard manual labor, and no better prospects than those of the laborers. There is no intention of putting young men fresh from college in responsible positions in the track department, over the heads of experienced foremen. They are put in the gang to learn, not to command, and to learn general practice and methods of work rather than to become simply expert section men. In view of the steady development of track work on scientific principles, and the valuable class of officers obtained by the combination of scientific and practical training, railway managements can well afford to give the necessary encouragement and opportunities. The time is near at hand when the

roadway department will be in the hands of engineers, and when it will be recognized that the trackmen are skilled laborers.

In regard to the details of the work of the roadmaster, he is responsible for keeping everything pertaining to the roadway in repair and in proper condition for safe use. He is held responsible for the maintenance and condition of the track on the division, for the safe keeping and proper use of all track material and tools, for the condition of the tool houses, section boarding houses, tanks, pumping stations, etc., and for the proper supply of water to trains. He is also responsible for the condition of yards, culverts, trestles, bridges, grade crossings, cabins, platforms, turntables, fences, cattle stations, and all minor structures. The rules and regulations which govern him differ on all roads, in accordance with local conditions and organization, but the following general outline of his duties, which is compiled from the rules of a number of railways, will give a good idea of the scope of his work and responsibilities. Where there are division roadmasters, or supervisors, their duties and responsibilities are practically the same, but on a smaller scale. Of course much of the work noted below has to be attended to by the foreman, but it is all included in the roadmaster's responsibility.

He must spend much of his time on the road, but must not neglect proper attention to office duties, such as the checking up of time-books, pay-rolls and records, the preparation of requisitions and reports, and the answering of letters from other departments. He is usually allowed a clerk to see to the correspondence and general office work. He must be frequently and systematically out on the track, not merely looking at it from the engine or the rear platform of a train, but walking over the sections, personally interviewing the foremen, and carefully inspecting all new work. He is usually required to pass over a part of his division every day, except when engaged in checking up time-books at the end of the month, and to pass over the whole of the division on foot or on a velocipede at slow speed at least once or twice a month, or oftener on mountainous or dangerous divisions. He should not use the section hand cars for his trips. He must record the dates on which he goes over the division, noting whether the trip was made on foot, by hand-car or by train; and must record all important work and its progress. He should be thoroughly posted as to the physical condition of the road and the daily disposition of his forces.

During his trips he must look closely into details of work, and talk frequently with the foremen, calling their attention to defects or bad practice, give them instruction and advice (but not "nagging" them), and being prompt to award either praise or blame. He should see that his orders are thoroughly understood and properly executed, particularly on special or important work; and should enquire of the foremen as to their plans for doing coming work. He should never issue orders directly to the men under his subordinates, as that tends to injure proper discipline and the respect for the foreman's authority, and he must remember that the foreman (and not the roadmaster) is in charge of the gang. He should, however, see that proper and competent men are employed. He should accompany the pay car over his division, to identify the foremen and help settle any disputes.

He must see that the foremen are properly supplied with time-books, time-tables, blank reports, etc., and that they properly use and return them; and also that they make proper reports of accidents, cattle killed, fences burned, etc. He must frequently and closely inspect the track to see if it is kept in proper condition as to line and surface, accurate gage, alinement and superelevation and widening of gage on curves. Frogs and switches must also be carefully examined as to condition and position. The accuracy of the foremen's gages and levels must be occasionally tested. He must see that the proper expansion shims are used in laying new rails, and that new ties and ballast are properly used. Also that all frogs, switches and fixed signals are placed in accordance with standard plans. The car and tool equipment, lamps, etc., must be inspected, to see that they are in efficient condition and properly used, and that all supplies are accounted for when requisitions are made for new material. Engineers' curve and distance stakes must be looked to, to see that they are not disturbed, and when they need renewing he must either set them out or report to the engineer. He must see that track signs, bridge tell-tales, mail cranes, etc., are in good and proper condition, and that all printed notices at farm crossings, etc., are properly posted. Fences, gates and gate fastenings must be looked to, and reports made of cases where farm gates are habitually left open, or where encroachments are made on the company's property.

The roadmaster has authority over the pumping station men, and must see that they keep the machinery clean and in order, and that the fuel is neatly stored and cared for. On the failure of water supply at any station, telegraphic notice, followed by a written report, must be sent to the superintendent. In winter he may also order the foremen to detail men to look after the stoves to prevent freezing up of the water stations. He must see that all buildings and their surroundings are tidy and in good repair, that section boarding houses are kept neat and clean and that proper food and accommodation are provided for the men. If this is not done it will not be easy to keep good men on the road, and track work will be expensive in consequence of being always in the hands of new men. He must also see that telegraph linemen, fence gangs and bridge gangs are afforded proper facilities and assistance in making repairs. Whenever any structure is being built or work is being done on the company's property by other than employees of the company, the facts must be reported, unless it is positively known that proper authority has been obtained. The roadmaster must exercise a general oversight of all work performed on the division by contractors, bridge carpenters, telegraph gangs, etc., in case anything should interfere with the safety of the track. A special inspection of all waterways should be made before the winter or rainy season, any necessary repairs being then made to trestle bents or banks of streams, and all obstructions removed.

Arrangements must be made for the proper execution of all new work ordered, and the roadmaster will obey instructions issued in regard to such work, including ballasting, laying new rails, putting in switch or interlocking work, laying additional tracks, rearranging yards, reconstructing bridges, etc., and the execution of the work should receive close attention. The roadmaster has full charge of all gravel and construction trains on his

division, must lay out the work for them, and make all orders for running them. He must also see that comfortable quarters and wholesome and sufficient food are provided. All orders for work done by construction and material trains are given by him, except in cases of emergency. Insufficient motive power on work trains must be at once reported, as construction trains are very expensive and require the best motive power to insure their economical operation. Record should be kept of time lost by work trains being laid out in passing sidings, etc., and a report made giving the reasons.

The roadmaster should annually inspect all the ties which the section foreman mark as needing renewal, and from this personal examination prepare a requisition for ties needed in the coming year, checking the foremen's counts and requisitions. This estimate must be sent in to the proper officer by a specified date each year. No ties must be removed without his approval, and those removed should not be disposed of until he has seen them. He must carefully examine the requisitions made by the foremen, and ascertain if the articles are really needed and in the quantities asked. Requisitions must be made in writing and sent by mail, the telegraph being used only in emergencies or when delay would result in loss to the company. He must personally receive all materials contracted for, such as ties, ballast, wood, etc., and must strictly enforce the printed specifications for the same, and arrange for handling and unloading or storing. Ties must be properly piled so as to facilitate inspection and marking with a hammer or brush. Wood ricks must not be more than 60 ft. long, and 6 ft. high, with 5 ft. between ricks to admit of proper inspection. Each rick must be thoroughly marked with whitewash or lampblack so that any misappropriation of wood can be checked. No material must be piled within 8 ft. of the rails. He must also supervise the storing and shipping of scrap, and its disposal at the scrap yard or pile. He must not permit old material to be sold or given away or otherwise disposed of by the men, and must see that foremen do not allow laborers to remain at the section boarding houses to chop wood or do odd jobs for the boarding master.

The roadmaster is expected to investigate and keep himself posted as to the wear of track material, rails, splice bars or special joints, ties, etc., reporting results from time to time, especially in regard to material under experimental trial. He should mark on a profile of the line all the new rails laid from time to time, giving the date, brand, and exact location with reference to the nearest mile post; this being in addition to the monthly written reports of rails laid. This enables the chief engineer to keep a correct account of the wear and life with reference to tonnage. All cases of broken rails should be carefully investigated in detail, and full reports made. Whenever a broken rail is found in the main track, a report should be made by the roadmaster after careful inevestigation (including the condition of adjacent joints, whether tight or open), and about a foot of the rail on each side of the break should be cut off, labeled and sent with the report for examination.

The roadmaster is authorized to discharge any supervisor or division roadmaster, section foreman, road watchman, conductor of construction train, or other subordinate, for neglect of duty. He suspends him and makes a report in case of accident resulting from such neglect. Changes

of foremen should always be made at the beginning of the month, except for good reason. In reporting the discharge of a foreman the cause should be stated, so that a record of the man's standing can be kept for future reference. A record of all foremen (and sometimes trackwalkers also) employed, discharged, resigned, transferred, promoted, married, deceased or sent to hospital, must be sent in monthly. When a foreman leaves the service, the roadmaster must see that all tools and other company property are properly accounted for and must examine his time-books to see that all accounts are correct. New foremen must be carefully instructed in their duties, and must be closely questioned to ascertain if they correctly understand them.

The roadmaster must see that section foremen, foremen of extra gangs and conductors of work trains are supplied on the first day of each month with the necessary blanks, such as check rolls, time-books, diaries, reports of work and materials, board bills, etc., and that the use of these blanks is explained to all new foremen. During his trips he should examine these blanks to see that they are being properly filled in. These returns are sent to him on the last day of the month, and he should examine them carefully, making the mark "Voucher" opposite the names of all men on the check rolls to whom he has issued time vouchers. The several reports, check rolls, diaries, board bills and time checks, together with the roadmasters' journal, must then be sent to the proper officer.

While passing over his division, he should always carry a book of blank time vouchers, so as to be able to issue a voucher to any trackman who presents a properly filled time-check. He should require the man to write his name in the blank space provided, so that the voucher may be used as far as practicable to identify the holder. Receipts on standard forms or blanks must be taken for every issue of time cards and for instruction books. These receipts are to be pasted in alphabetical order in a book for preservation and reference.

The roadmaster is required to keep a journal or diary, in which he must enter the location and the dates of beginning and ending of all work under his charge, such as grading and laying sidings, changes of line, laying new rails or ties, ballasting, experimental ties or joints, etc. He has also a pocket notebook, in which he records how each trip is made (whether on passenger or freight train, on handcar or on foot), and also any points de-interest for record or of use in making up his returns, such as material delivered or required, the number of men employed, etc. As a check on the time of the section men he should note here the number of men in each gang as he passes. These books should be of a uniform standard size, supplied by the company, and sent to the superior officer each month. Memorandum books and all blanks are obtained from the office regularly or by requisition. He should have his watch inspected once every three months and should compare it with standard clocks and with the watches of the foremen as often as possible, seeing to it that the foremen take his time as correct. To the roadmaster should be made all applications for detailing men from the section gangs to assist fence gangs, telegraph repair gangs, or bridge gangs, or to clear station grounds and yards.

He must be familiar with the train rules, special orders, etc., and keep in communication with the transportation department. Disregard of sig-

nals by trainmen must be promptly and invariably reported. Locomotives and cars with worn and flat wheels must be reported, as they are very injurious to the track. He must see that the track and roadway are in proper condition for the winter. In times of storm he must keep the superintendent fully advised of the condition of the road, and he must see to the proper distribution and work of trackmen to help the snow gangs on their sections. The roadmaster must closely investigate every accident that occurs on his division, and make a full written report in the proper form, giving the cause of the accident and all information possible. He must be ready at all times, both day and night, to render any assistance that may be called for in case of accident or detention to trains. On receiving notice of a wreck he must proceed to it at once, take charge of the track forces not required in removing the wreck, and put the track in condition for the passage of trains, or build a temporary track around the wreck, all with the least possible delay. Such material as broken rails, axles, etc., which may be of use in determining the cause of the accident, must be preserved. When cars are broken up or burned for removal at a wreck, he should note the style of car, and the number and initials of each car thus destroyed.

Section Foremen.

The section foreman is the most important of the men in the working force, and should be a man of good judgment and firm character, so that he can rule his men and get on comfortably with them, while at the same time getting a full amount of work done, and not allowing them to shirk or "soldier." He should be able to read and write and keep simple accounts, so as to keep the necessary records of labor and supplies, and to make out his requisitions for material. All reports and requisitions are sent to the roadmaster. For this clerical work he should have a desk and office in the section tool house. He is usually required to walk over his section every other day, or at least once a week, this depending upon the season, the length of the section, the condition of the track and the amount of traffic. He has also to make a monthly inspection of and report upon all culverts, trestles, bridges, tunnels, etc., on the section, and must also inspect any such structures at times when they are liable to be damaged by floods or otherwise. He should be subject only to the orders of the roadmaster. Train dispatchers, station agents, claim agents, bridge foremen, tie inspectors, foremen of fence and telegraph gangs, etc., should not be allowed to give orders direct to the section foreman, or to call upon him to supply men for any purpose, except in case of emergency. He should on no account throw switches for trainmen. Where two or more gangs work together on emergency work, as in case of accident, the senior section foreman is in charge, subject to the direction of, or until the arrival of, the wrecking foreman, roadmaster, engineer or superintendent, as the case may be.

As to section foremen working with their men, it may be said that with small gangs, up to, perhaps, five men, the foreman can very well join in the work and still keep a general oversight of it. With a large gang of eight men or more, or with extensive work in progress, he will, as a rule, have all he can do to see that the work is being done properly, especially when there are new men to be broken in. A foreman, however, who works

regularly as one of the gang is not likely to have their respect or to get the best work out of them. This, of course, depends partly upon the character of the work. Putting in switches or lining up track will require much watching, while in cutting grass, or in general trimming up (even with a large gang), the foreman can well work with the men, and at the same time keeping an eye on the progress of the work as a whole. It is his duty to direct the operations, and to see that they are carried out properly, and to supervise the track work generally, being careful to have the work done thoroughly and systematically and not at scattered points on the section.

Where large gangs are worked it is a good plan to permit the foreman to appoint an assistant foreman, who ordinarily works with the gang, but takes charge in the absence of the foreman. In promotions, the assistant foreman should be given the first chance. The foreman should have power to appoint and dismiss his assistant, making the necessary report of the circumstances, and being, of course, responsible for his ability and for all the work done by him, the roadmaster having nothing to do personally with any trackman below the grade of foreman. The assistant foreman should be selected not only for his technical or practical skill, but also for his executive ability in directing the work and handling the men. He may be given a slight increase in pay over that of the regular laborers.

The foreman employs and discharges the men of his gang, and also the bridge and other watchmen on his section, and keeps proper records of all the men and their work. He must treat his men properly, without fear or favor, and without the use of profane or abusive language, endeavoring to promote harmony and good feeling among them. When the men do not live at a section house, he should know their addresses, and arrange a system by which one man can call others in case of emergency at night. He should have authority to employ extra men temporarily during heavy snow, and should have a few extra men assigned him when any extensive switch work, etc., has to be done.

It should be his aim not only to keep the section in safe running condition, but to steadily improve its condition and appearance. He has charge of all repairs on his section, and is responsible for the proper inspection and safety of the track, bridges and culverts. He must see that ditches are clear, and that drainage is not obstructed, that weeds and grass are kept cut along the right-of-way and around trestles; also that ties are tamped, rails properly spiked and jointed, and track in line and surface in good condition generally. He attends to the fences and telegraph lines, resetting poles when necessary; and also sees that water stations are in order and water barrels at trestles kept filled. He must also see that the gang has the proper equipment of tools and supplies, and that this equipment be kept in good condition, properly used, and properly arranged in the section house. He must have a reliable watch, and must daily, if possible, compare it with and regulate it by the clock in the telegraph office at a station or signal tower on his section, so as to keep standard time, and so be prepared for regular trains. He must have a copy of the latest time-table, be familiar with train rules and schedules, and look out for signals on and messages from passing trains. Failure of trainmen to respect his signals or to answer them with the proper

whistle must be reported. In heavy rain or wind storms he should patrol the section with sufficient men to ensure safety to trains by setting out signals and torpedoes if any defect is discovered that cannot at once be remedied. Such defect must be at once reported by telegraph to the roadmaster and superintendent. In case of accident, he must go to the scene with his men, even if it is not on his section.

The foreman is supplied with time-books, pay rolls and diaries, and carries them with him, ready for inspection by the roadmaster at any time. All entries must be written up in the time-book, etc., every night for the day just closed, and then all footed or totaled up together at the end of the month. The books, board bills, etc., must be properly entered up and certified, and must be sent to the roadmaster by a night train on the last day of the month, or by the first available train on the first day of the new month. On some roads he is furnished with duplicates of these reports, so that he can retain copies of the returns made to the roadmaster. In the check roll or time-book he enters daily the time worked by each man, and on the diary he records the total time made by the gang. Entries of materials used in construction or repairs must be made daily and footed up at the end of the month. He also makes reports of material used and on hand, of work done, fences or other property burned, cattle killed by trains, and makes requisitions on the roadmaster for material required. The time-book entries must show not only a correct report of the time worked by each man, but also the kind of work upon which he was engaged each day. The character of the weather should also be noted.

Should a man leave or be discharged before the end of the month, the foreman gives him a time-check (showing the amount of time he has worked) which he can present to the roadmaster, who will take it up and issue in its place a time-voucher, which is payable by any agent of the company having funds for this purpose. The foreman must require the man to sign his name on the back of the time-check if he can write, and the man can, if he wishes, retain this check, which can be used to identify him to the roadmaster or in the pay office. To secure payment to the section-house keeper and others furnishing board and lodging to track and bridge men, the foreman supplies such persons on the first of the month with blanks for "board due," which they are required to properly fill out and have signed by the men from whom the amounts are due. These blanks are returned to the foreman on the last day of the month, and from them he enters the amount due by each man in the "board" column of the check-roll, opposite the man's name. Different railways have different styles of time-books, blanks, etc., and particulars of these will be found in Chapter 27.

Trackwalkers and Watchmen.

In addition to the regular work on the track, the section must be inspected at least once a day (except Sunday) by a trackwalker. On most important lines this man is in addition to the regular section gang, and he usually starts out in the morning in the opposite direction to that taken by the gang, while on roads having much night traffic he must also go over the section in the evening. The time of starting out can usually be arranged so that the man can go over the section shortly before the princi-

pal trains, and can, perhaps, return by train. In the afternoon he may work for a few hours with the gang, and then go over the section again, returning by train. On double track, he may make a round trip over each track (one by day and one by night), and on four track lines he passes once over each track. In summer, and in fine settled weather, the trackwalker can join the gang in the afternoon, but in stormy weather, or when there is liability of such dangers as washouts, the blowing of trees or telegraph poles upon the track, etc., he should spend all his time patrolling the section. After a very heavy storm the trackwalker and one of the laborers should go over the section and look out for any damage requiring immediate attention.

On the Erie Ry., the trackwalker works under the direction of the foreman. In summer he makes one trip daily over that part of the section which is not covered by the foreman on his way to and from work. In winter or in stormy weather he covers the section twice daily. When tie renewals are being pushed he works with the gang for the remainder of the day, and in the spring and autumn he spends the remainder of the day in tightening bolts and replacing broken spikes. At all times he gives immediate attention to any necessary light repairs of frogs, switches, etc. On the Illinois Central Ry. one of the section men acts as trackwalker, except that on some portions of the line where traffic is unusually heavy an extra man is employed as trackwalker. The Chicago, Milwaukee & St. Paul Ry., and some other railways, only employ trackwalkers at certain seasons of the year, when it is made necessary by reason of heavy rains or other special conditions. Other roads do not employ regular trackwalkers, but send a man over each section on a velocipede, leaving all repair work, etc., to the section gang. The foreman is sometimes required to act as trackwalker, but this interferes with his charge of the gang, except that on roads with light traffic he can go over the section after he has first started the gang at work. On branches or lines with light traffic, one of the laborers may act as trackwalker, making one trip and then returning to work with the gang. Where there are many switches or signals to be attended to, the lamp man may act as trackwalker, making two round trips over the section; the first in the morning to extinguish the lamps; the second in the afternoon to fill, trim and light the lamps. In such case the foreman or a laborer should make an extra trip in bad weather.

The day trackwalker is ordinarily equipped with a track wrench, a light hammer (having one end pointed), 2 red flags, 4 torpedoes, and a few bolts, nuts and spikes in a bag, while sometimes he also carries a tamping pick. On sections with dangerous rock cuts he may also have a few sticks of giant powder or other convenient and safe explosive to shatter rocks that may have fallen upon the track. It is sometimes recommended that he should also carry a pair of short pieces of plain splice bars, with one hole in each, so that he can bolt these to any broken rail, putting the bolt through the open space of the fracture. This is rarely necessary. In walking over the track he looks out for broken rails and burnt ties, raises low joints, picks up loose material and places it at the side of the track. tightens loose bolts and spikes or puts in new ones, examines frogs, switches and switchstands, and in warm weather throws stub switches to see that they work freely, reporting them if stiff. He must see that cars

on sidetracks are clear of the fouling points. He also has to look out for broken or defective signals, to look out for and repair fences, close farm gates (reporting any that are habitually left open), look out carefully for fire on bridges and trestles, and see that the water barrels on wooden structures are kept full; he must also see that culverts are clear and cattle-guards safe, drive stray cattle off the right of way, and in general "do anything and everything to protect the railway from accident." After a heavy storm he must be specially observant, and look out for evidences of washouts or of slides of banks or cuts. In winter he must also clear snow where it is packed about frogs, switches, guard rails and the flangeways of crossings. The night trackwalker is only expected to walk the section and see that the track, etc., is safe; he is usually provided with a lantern, red lamps and torpedoes. When the trackwalker finds any place unsafe for the passage of trains he must place a red flag (in each direction on a single track line) at a distance of 90 rails or 15 telegraph poles, and place a torpedo on the rail. The torpedo should be on the rail on the engine-man's side of the track, and the flag on the same side of the track, 3 ft. from the rail. Where the block system is in force, the trackwalker's beat may be between certain block towers, and he may be required to enter the tower and sign his name and the time in a record book, the signalman also signing the record. Watchmen at special points may also be required to report at a block tower at stated times.

It will be seen that the trackwalker has an important and responsible position, which should only be filled by an experienced and trustworthy man. It is sometimes assumed that his work is principally to look after loose bolts, but in the main the amount of trackwalking is independent of the work done in tightening the bolts, and while some roads do not permit the trackwalker to touch the bolts unless he sees something wrong, yet no reduction in the trackwalking would be justified, even if there were no bolts to tighten. Too much care can hardly be taken in guarding the track, and in watching it in time of storms to prevent accidents as far as possible and at least to prevent accidents to trains. With track of average condition, the trackwalking usually costs more on curves than on tangents, unless more attention is given to the maintenance work on the latter. Watching also costs more, as an engineman cannot see ahead on a curve, and in case of a storm or flood, it may be necessary to station a watchman in a cut on a curve, when it would not be necessary if the track were on a tangent.

Any particularly dangerous spots, such as tunnels, loose rock cuts, sliding slopes of cuts or banks, rock cuts in winter, and culverts and trestles in time of flood, should be guarded by a watchman. This man should be provided with lamps, flags and torpedoes, and, if necessary, with tools (a pick, shovel, ballast hammer, wheelbarrow, etc.), and some sticks of giant-powder to break up rocks that may fall on the track. Where watchmen are stationed permanently at such places, cabins similar to gatemen's cabins should be provided. These men must be of sufficient experience to appreciate the responsibility of the post and to be relied on in case of emergency. On some roads, including the Erie Ry., the watchmen on rocky divisions are supplemented by a special "rock gang," composed largely of quarrymen, who are experienced in climbing and in detecting

loose or dangerous rocks, the removal of which is done by them. This gang is in charge of a special foreman.

Grade-crossing watchmen or gatemen have usually nothing to do with the track, except to see that the flangeways are clear and that the planks are securely fastened to the ties. Bridge watchmen must see that water barrels are kept full on wooden bridges and trestles, and must follow every train and extinguish any hot cinders that may have fallen from the engine, and at the same time look for signs of sparks from the engine which may have lodged in the upper part of the structure. They must keep all combustible material cleared from the vicinity of the bridge, keep abutments, copings and bridge seats clean, and report any bulging or sign of cracking of the abutments or masonry. They must also watch for any evidence of undermining of piling or abutments; examine the structure and report to the section foreman any decay or defect, slackening of nuts, loose rivets, etc., and must observe the structure during the passage of trains, noting specially if trains cross at too high a speed. Every train must be signaled by a white flag or lamp if all is safe. They should prevent all persons, other than employees, from walking over the structure. Drawbridge tenders must look after the locking and other gear and the signals or gates, reporting promptly any sign of defect in the structure or in the operating, turning or locking machinery. Bridge watchmen and drawbridge tenders may be set by the foreman to do incidental work when not engaged in their special duties.

Force and Labor.

The number of men employed upon each section depends upon the financial condition of the company, the condition of roadbed and track, the season of the year, and the amount of traffic. This latter is one of the most important considerations. On the Illinois Central Ry., with wide extremes of track and traffic (700 train movements per day on the eight tracks of the Chicago terminal, and one local train each way per day on the Dolgeville branch), the number of men varies from 1.1 man per mile on busy double-track sections to ½-man per mile on branch lines where the traffic is light. The maximum gang is about ten men and a foreman in summer on a single track. The minimum is reached on some Western roads with light traffic, where the foreman and one or two laborers are required to look after 6 to 10 miles of single track for 4 to 6 months of the year, and under such circumstances the question of appearance of the track must be left out of consideration. The average, however, as shown by the table already given, is 5 to 7 men on single track in summer, and 2 to 4 men in winter. With a small gang, the section should not be too long, as in case of finding a broken rail, etc., there may not be time to flag both ways or to notify the men of the adjacent section to help make repairs.

As an average, it is estimated that 1 man per mile of single track, or 1½ men per mile of double track, with a foreman and trackwalker to each section, will be force enough to maintain the track in proper condition if the material is good. Where sidings exist it is usual to take two miles of important siding or three miles of unimportant siding as equivalent to one mile of main track. As a rule, it is not economical, though sometimes

necessary for financial reasons, to reduce the force below about a man to two miles on ordinary sections, as such a reduction leads to deterioration in track, with consequent injury to the rolling stock, discomfort and danger to passengers, and eventually an inevitable heavy expenditure for repairs due to insufficient expenditure in maintainance. The number of men is increased in the spring and reduced just before winter sets in; but the number should be reduced gradually, so that work in hand can be safely and thoroughly finished and cleared up, and not hurried over. In the winter, when the rails, ties and ballast are in good condition, and in a locality where no large force is necessary to clear snow, the number of men may be cut down to two or three, besides the foreman, keeping just enough to do watching, clearing and occasional shimming. For handling snow extra men must be engaged, and the foreman should have authority to employ such extra men on emergency.

The number of switches and frogs on the section has a considerable influence on the amount of work to be done and the number of men required, varying, of course, with the amount of traffic. The New England Roadmasters' Association in 1895 adopted a report to the effect that 15 switches and frogs on an ordinary section would necessitate the employing of an extra man in the gang. This refers to both main track and yards under conditions of moderately heavy traffic, and the number of switches and frogs requiring an extra man would be less than 15 in the case of a busy yard or terminal. Where yards occur the section must be shortened or the force increased, but with large yards it is best to have a separate gang or gangs under a yard foreman, with assistant foremen if necessary.

Many railways employ extra or "floating" gangs to do fencing, relaying rails, ballasting, general surfacing, ditching, tile drainage, etc. This gang has a work train, with complete tool equipment and living or boarding cars. New switch work is sometimes done by the extra gang. It is far better, however, to have all ordinary work on the section done by the regular gang, and a good foreman and gang ought to be competent to do all switch work, with the occasional assistance of a few extra men for extensive work. The extra gang aims to get its work finished as quickly as possible and has not so much regard to the permanence of the work as has the gang in permanent charge of the section. Besides this, the frequent appearance of the floating gang spoils the discipline and the self-reliance of the regular gang, so that the men and foreman get in the habit of expecting to have any little work out of the ordinary line to be done for them, which is an idea not conducive to good work. It is, therefore, well to have as little work as possible done for the regular gangs, and then they will be more capable and self-reliant, while the foreman cannot escape the responsibility for work done or neglected by him. On the Ohio River Ry., however, the bulk of the work is done by floating gangs, under the system already described.

About once a year the track must be surfaced, lined and gaged, have new ties put in, and low joints raised, etc. This work can best be done in the spring, so that as soon as the frost is well out of the ground the gang should be filled up to the full number that the foreman can handle, say 10 to 15 men. The work can be done to best advantage by commencing at the end of the section and working back. All heavy work can

thus be done in time for the increase of traffic in the summer, and the track will then be in such condition that the force may be cut down when farm work and harvesting begin to take the extra men away. If the heavy work is thus promptly disposed of, the track can be maintained during the summer with a force of about 1 man per mile, which is the lowest economical average for ordinary work. In the autumn there is ditching and clearing to be done, and the track to be put in condition for the winter. When this is done, the force can be cut down to the winter allowance. The work of the sectionmen should be reduced to a routine, and nothing outside of their regular work required of them, without the authority of the roadmaster, through whom should come all orders to the foreman, as already noted. It is bad practice, and no economy, to allow the track to get in bad condition in summer for want of enough men to maintain it, as a larger force than usual must then be employed in the winter or late autumn, when work cannot be done to good advantage.

There is too often a tendency to leave anything a little beyond the ordinary work, or any unfinished work, to be attended to on Sunday, but this is a most reprehensible practice, spoiling the men's temper and generally resulting in a loose kind of work. It is also detrimental to good work and discipline, for the men cannot keep up a high standard of efficiency nor can they have high respect for foremen who insist upon Sunday work. The practice should be strictly forbidden, and the foremen made to understand that the rule will be strictly enforced. Men need, and should have, a day of rest, for its physical and mental as well as moral effect, and if they are required to work for 13 days they will not do a fair day's work during each of the last 6 days. In case of emergency or accident, etc., the men should, of course, go to work at once, but it is entirely unnecessary to do ordinary work on Sunday. Such men as Charles Latimer (Chief Engineer of the New York, Pennsylvania & Ohio Ry.), James Furber (General Manager of the Boston & Maine Ry.), and Col. W. H. Paine, were prominent in their advocacy of Sunday rest on railways, and Mr. Latimer stood at the head of American roadmasters in his day. If the roadmaster has properly instructed the foremen and laid out the work properly for them, it will be possible to get the work done on week days, except in special cases on busy suburban lines, terminals, or where the traffic is exceedingly heavy. Consequently the work should never be done on Sunday without good reason. It is an expensive practice to spend 6 days in preparing for a large amount of work to be done on Sunday, with all the section gangs that can be conveniently got together, as the work is generally done with a rush, and the best work can never be done where a number of foremen are working on some other man's section. Besides the question of economy, it must be remembered that the sectionman has few opportunities of spending time with his family and friends, and to deprive him of these even on Sunday is not only unfair, but is opposed to the permanent interests of his employers. The man (whether foreman or laborer) who is best to be depended upon is the man who gets fair treatment and a fair day's pay for a fair day's work.

Another bad policy which is frequently found in track service is that of employing the lowest and cheapest grades of labor on the track. Good results are not to be expected from such a class of labor, and the em-

ployment of foreigners who cannot speak the language, but have to be communicated with by signs, is certainly not conducive to good work. Inefficient and careless men should be discharged without delay, whether foremen or laborers. The improvement in the grade of labor rests almost entirely with the railway companies, for good men are usually to be had at reasonable wages. It has, however, been pointed out by the author (in a paper on "The Relations of Track to Train Service" in "Engineering News," June 15, 1893) that the directors and the higher officers of the financial departments, very generally fail to recognize the importance of the track, and to realize the economy of proper maintenance. Not only are renewals delayed, old structures patched up, and safety equipment dispensed with, but track forces are reduced and their wages kept down. There is a strong sentiment of discontent among section men and foremen at the lack of remuneration and encouragement; and it is hard to keep a permanent gang, except on roads where a more enlightened system is in force than that of considering any tramp or laborer as good enough for trackwork. The trackmen's work is little regarded; yet if these men relaxed their vigilance or failed in their duty, not all the skill and faithfulness of the enginemen and train crews, or the elaborate equipment of the trains, could give a satisfactory train service or prevent accidents. A little inattention to a weak spot in the track, a neglected loose joint, a defective switch or frog, an overlooked broken rail, or spikes not properly redriven, and the "lightning express" goes into the ditch with more or less disastrous results, and involving more or less expenditure for damages, repairs and compensation. Trackmen who understand their work are valuable, and should rank as skilled laborers, and the railways should endeavor to retain their services by encouragement in pay and promotion. Faithfulness, intelligence and skill are required, as well as muscular ability, but the first three requirements can hardly be expected from the grade of men whom the foreman too often has to employ. Men who hold permanent positions (contingent upon merit), and have also a pension in view as a reward for long and faithful work, have more regard for the interests of their employers and are more apt to try to educate themselves in their work. Unskilled laborers may be employed from time to time for extra work; but it is as false economy to have a constantly changing gang of green sectionmen as it would be to follow the same practice with enginemen, trainmen or machinists. Such men will use more time and material in doing bad work than experienced men will use in doing good work.

On some Southern roads there is an "apprentice gang," in charge of a foreman, and the new men are given proper instruction in this gang, instead of having to pick up their knowledge as best they can while working with a regular gang. Men trained in this way are worth having, and will often make good foremen. Other roads have a system for educating their employees in the work of their departments. It has already been noted that in large gangs it is well to allow the foreman to appoint an assistant foreman, who will work with the gang while the foreman is present and take charge of it when he is absent. A system of rewards, either as premiums for work or as an increase in pay to the better and older foremen, is employed to advantage on several railways. Further particulars of this are given in another chapter.

Men should not be employed who are under age, elderly, weak or incapacitated, or who suffer from deafness, consumption or other diseases. The foreman must not excuse habitual neglect of duty, but should promptly dismiss or suspend unfaithful employees. No man should be discharged without cause or for the purpose of making place for another, but all men should understand that they are in line of promotion, their advancement depending upon faithful discharge of duty and capacity for increased responsibility. On most roads the use of intoxicating liquors by the employees on duty is strictly forbidden, and this rule should be most rigidly enforced, while men who habitually drink too much when off duty should be dismissed. It may not be amiss to refer here to the admirable "white button" temperance movement which was originated among railway employees of every grade of service by Mr. L. S. Coffin. Smoking, while on duty, should also be prohibited. It is a good plan to have a rule prohibiting the offer of testimonials or presents to superiors, or the acceptance of such by the superiors.

An important feature which has been introduced into the maintenance of way forces of some railways is what is known as the Brown system of discipline, as a substitute for the common and very objectionable system of punishing men by suspension and dismissal. The evils of the latter system and the demoralization which results from suspending the men from duty are well known, to say nothing of the hardships which it works for those dependent upon the men. Under the Brown system (which has long been used in the transportation department), when a rule is broken, orders are disobeyed, or any irregularity occurs which calls for discipline, a bulletin is prepared and issued to all the roadmasters and foremen, stating the offense and giving some good advice to prevent its repetition. The bulletin may also be posted up in stated places. No names are given, but the man who is at fault usually receives a marked copy, and a record is kept for each man. This system gives good results, and is in general satisafctory to the men. The disgrace of being bulletined (even though it is a private reprimand) is to the average man as great as that of suspension or discharge. It hurts his pride quite as much, while it does not induce him to bluster and seek to justify himself publicly. Consequently the moral or disciplining effect is probably much deeper and more effectual than that of suspension or discharge, while it is not attended by the evil results to the man and to the track forces which are attended by such suspension or discharge.

Work-Train Conductors.

The conductor of a work train is usually appointed by the roadmaster, subject to the approval of the division superintendent or other officer of the transportation department, and must obey orders from the superintendent in regard to safe movement of the train. He must see that all ditching, ballast and boarding cars are in good running order, that the boarding cars are clean and neat, and that good, substantial food is furnished to the men. He must be familiar with the time-table and train rules, and study the rules and instructions issued to track and bridge men, and also familiarize himself with all kinds of work pertaining to the maintenance of track. Ditches must be cut according to the direction of the section

foreman. He must see that care is taken in unloading material, that new ballast is cleared to leave a proper flangeway along the rails, and that skids are used in unloading rails. In distributing new rails, he must note in a book the initial and number of each car, and the number and lengths of rails on each car.

He must notify the division roadmaster when ordered by the roadmaster to distribute material, such as ties, rails, ballast, etc., so that the division roadmaster can notify the section foreman and be with the train while working on his division. He makes a weekly report of work done, materials used, delays to work, insufficient power of engines furnished, etc. When the train is delayed and likely to be held for some time, he must put the gang at work ditching, weeding, or clearing station grounds and yards. He must understand that his desire to get the work done and his train out of the way must not lead him to do hasty or careless work. The train should always lay over at a telegraph station at night.

The foreman of the work-train gang should be the conductor, sharing responsibility with the engineman, as in regular train service, for a conductor who has no other duties outside the train is apt not to work in harmony with the foreman, who is interested in and held responsible for a fair day's work. A foreman who acts as conductor gets a good knowledge of the trains, which enables him to arrange his work to the best advantage (especially in the smaller items of work, which consume so much of the time), so that it can be done within the working limits assigned. He should be an expert track foreman, and be provided with an assistant foreman, and also with a timekeeper, if he has a large gang. Further particulars are given in Chapter 22, under the heading of "Ballast and Work Trains."

Minor Track Officials.

Master Carpenters.—These usually report to and receive orders from the roadmaster. They have charge of the repairs of buildings, bridges, trestles, stations, water tanks, pumping stations, etc. When making ordinary repairs they must see that the main tracks are unobstructed, or if it is necessary to obstruct these tracks they must obtain an order from the superintendent and must protect themselves by flag in the usual way.

Yard Masters.—These report to and receive instructions from the division superintendent (and also from the trainmaster or other officer in charge of transportation), and they also comply with instructions from the station agents. They usually have to do only with the handling of cars, but are sometimes also in charge of the track work of the yard.

Switch Tenders.—These report to and receive instructions from the station agents, while in yards they report to and are under the direction of the yard master or station master.

Bridge and Building Department.

This department is frequently connected more or less closely with the maintenance-of-way department, as already described. It has charge of the construction, maintenance and renewals of all structures, and one of the important occupations of its superintendent should be the study of means for promptly rebuilding wrecked or damaged structures, and for replacing

trestles, wooden bridges, etc., with solid banks and culverts or new iron structures. Turntables, track and stock scales, ash pits, water tanks, wells, pumping plants, mail cranes, coal handling machinery, etc., are frequently in charge of this department. There is usually a general yard for lumber and piles, while emergency stacks of timber are kept by the master carpenters at points on the divisions. This is a better arrangement than having a large stock on each division.

The department is generally in charge of a superintendent of bridges and buildings, who must inspect all the bridges once in three months, and all other structures under his charge once a year. He also tests and certifies as to the accuracy of all scales. He may report to the roadmaster or general superintendent, or to the division superintendent, the latter being the better plan, especially if the division superintendent is an engineer. Under the superintendent of bridges and buildings are the bridge foremen and their gangs, and sometimes the master carpenters. Further particulars of the work will be found in Chapter 21, under the heading of "Bridge Work."

Signal Department.

As already noted, the signal department is very often subordinate to the engineering or maintenance department, which is the most systematic plan of organization. The department is of such comparatively recent date that its actual organization has not been well systematized, and there is in fact some difficulty in finding men of sufficient skill and training for the higher positions, men who can understand the principles as well as the mechanism. For this reason, the signal department, as well as the roadway department, offers a field for the graduates of engineering schools. The charge of and responsibility for signal apparatus of every description on the road (switch targets and signals, train-order, block and interlocking signals) should be concentrated in the signal engineer, with a suitable staff of inspectors, repairmen, signalmen, etc., under him. The employing and discharging of these men, including the signalmen, should be in the hands of the signal engineer and not of the superintendent. In many cases the signalmen are mere operators, having little mechanical skill or knowledge of signal apparatus, relying on the repairmen entirely, but it would be better to employ men who do know something about these matters, as in many cases the men would detect and remedy slight defects in the apparatus which might otherwise cause considerable detention.

The practice of the signal department in relation to the general organization of certain railways has already been described. On each of the two systems of the Pennsylvania Lines, there is a signal engineer reporting to the general superintendent, and a supervisor of signals on each division, who reports to the signal engineer and also to the engineer of maintenance of way of his division. Levermen and lampmen report to this supervisor. On the Chicago & Northwestern Ry., the signal engineer has a corps of maintainers, battery men and lamp men in charge of about 40 blocks, or 20 miles of double track; battery men and lamp men have about 20 blocks each. The maintainer must ride over his entire district twice a day, making any necessary repairs, etc., and reporting to the signal engineer. He must so arrange his work that every part of the apparatus under his

charge is inspected and tested once a month. On the Cincinnati Southern Ry., it is considered preferable to center the responsibility, and there is a repairman to each 14 miles, having entire charge of all the signal equipment and apparatus. The signal engineer or inspector should make frequent trips, but not periodically, so that the signalmen and repairmen know that they are likely to have a visit at any time to their towers or districts.

CHAPTER 17.—TRACKLAYING AND BALLASTING.

Under the ordinary system of organization, the engineer who has had charge of the grading and masonry in construction, usually has charge also of the tracklaying, and sets the center and grade (or ballast) stakes. On roads having a maintenance department independent of the engineering department, however, an engineer of the former department will take charge of tracklaying when the latter department has completed the construction to subgrade. Under either system, the engineer in charge of tracklaying runs in upon the completed roadbed the alinement which has been used in construction, and is able to run the line with much greater accuracy, and to rectify minor inaccuracies in the former running of curves. The anchor bolts for steel bridges should not be set until this final alinement has been made. He has a copy of the field notes locating the position of each intersection, P. C. and P. T., the stakes by which these are referenced, and notes of the curvature and length of curve. In many cases he finds that the curves will not fit, and the P. C. must be moved backward or forward until the P. T. falls on the given tangent. The line is monumented as soon as possible after this work. Pieces of rail about 4 ft. long, driven down with their tops a short distance below track level, make convenient and satisfactory monuments; a cross being cut on the top for the exact point. For a double track railway, the center line stakes are sometimes set between tracks, and the tracklayers are provided with measuring boards with which to get the proper lateral distance for the line rail of each track. In some cases, the engineer prefers to run a center line between the rails of each track or outside of the rails and close to each track. In general, center stakes are driven at intervals of 100 ft. on tangents and 50 ft. on curves, or sometimes 25 ft. on transition curves. Many old track foremen consider that centers are required only at intervals of 300 or 400 ft. on tangents, and that setting them oftener is unnecessary and a criticism on their ability to line track. It has already been pointed out, however, that instrument work rather than "sighting" should be employed in lining first-class track. In any case, stakes should be set at intervals of at least 200 ft. on tangents and 50 ft. on curves, and at each end of every spiral or transition curve.

Grade or ballast stakes are set generally for level of top of rail. These are set on both sides of the track, about 5 ft. from the center line, but their location should be governed by the question of avoiding disturbance by the dumping of the ballast. This will differ a little according to the style of cars and unloading of ballast; and (on double track) according to

whether one of the two tracks is an old track where no change is to be made and where a grade stake for top of track can be set safely without fear of its being disturbed. They are set 100 ft. apart on tangents and 50 ft. apart on curves, giving the proper elevation for curves. On curves, the stakes are usually set for the inner or lower rail, this rail being kept at grade and the superelevation put entirely in the outer rail. On roads using a spiral or taper approach, grade stakes are also set opposite P. C. and P. T., and at each change point of the taper. Large stakes or posts are sometimes set clear of the roadbed at these points and at the beginning and end of curves. No care is required in securing an exact distance from center line for these grade stakes. In fact they are less confusing to the tracklayers if not in regular line, as inexperienced men are less likely to mistake them for alinement stakes. A red chalk mark should be made on top of every grade stake where the top of it is intended to be the exact top of rail level. Otherwise the stake should be distinctly marked to indicate the distance above or below top of stake for grade. It is well not to set these stakes until they are needed, as if set ahead of the tracklayers they are pretty sure to be disturbed. At grade intersections where vertical curves are used, the stakes are set for the proper elevation or profile.

Before tracklaying, the roadbed should have been properly dressed by the contractor to the exact subgrade, or the subgrade plus any allowance for settlement which has been decided upon. This is done by having dressing or trimming stakes set by the engineer for the use of a small grading gang furnished by the contractor after the first rough grading has been done. There should be no hollows or inequalities left by the grading forces for the tracklayers to fill or level out, as such work is troublesome for the track gang and causes much delay, requiring different class of tools from those used in a tracklaying gang. The result would be that the work would be to a large extent neglected. This dressing or trimming is expensive and most contractors fix their price for grading to include this work. If the work is not done by the contractor, it should be attended to by a small grading gang working ahead of the tracklayers and under the orders of an engineer. In some cases the roadbed is inclined on curves to approximately fit the superelevation.

The engineer in charge of tracklaying has to see that arrangements are made for keeping the contractor supplied with the proper amount of material, and also to see that the materials are properly used, and that the work is properly done. He should specially look after matters of detail, except, perhaps, in these now rather rare cases when a long line of track has to be laid with the greatest possible rapidity. As a rule, the railway company supplies all material, and a supply train for delivering this material at the end of the completed line, ready for the contractor, who is in charge of the entire work of tracklaying (including the distribution of the material from the stated points of delivery), subject to the supervision of the company's engineer. Similar arrangements are made when the company does the work with its own men. It is to be noted that tracklaying is a work which requires a clear head, or good judgment, and a faculty for handling large bodies of men and keeping them all at work together without driving them or causing them to interfere with one another. This applies to the foremen as well as to the engineers, and it is further to be noted that

tracklaying trains (like work trains) should be handled by powerful engines in good condition, and not by old engines which have outlived their efficiency for regular service.

In regard to the speed of the work, particulars of which are noted further on, it must be understood that it is rarely practicable to maintain a high rate of progress continuously. Uncompleted bridges or sections of grading are likely to stop work occasionally, so that the work of tracklaying is largely governed by these conditions rather than by the means of carrying it on as rapidly and economically as possible, irrespective of delays, etc.

Tracklaying by Hand.

The material train, with a properly arranged quantity of track supplies, is run to the end of the completed track, and the work is usually begun by hauling the ties by teams and distributing them alongside the roadbed. The tie gang then places the ties at right angles to the track (or radially on curves), spaces them accurately, locates the joints by a 15-ft. pole, picks out the large ties for joints where this is required, and then lines up the ties on one side of the roadbed by means of a cord stretched between stakes set half a tie length from the center stakes. On curves this rope is first stretched as on tangents, and then curved by measuring the middle and quarter ordinates for the degree of curve. The ties should not be laid too far ahead of the rails or the joint spacing may be found to be incorrect, requiring rehandling of the ties under the rails, which is troublesome. The full number of ties should be laid at once, and not a few ties to each rail length, leaving the other ties to be slipped in under the rails, as the rails are likely to be kinked by the running of the material train over such a track. The ties should, if necessary, be adzed to give proper seats for the rails.

Rails are then run from the train to the head of the track on a push car or horse car. The rail gang takes off two rails, half bolts them at the heel joint, sets the head ends to gage at the front end by a grooved track gage, and secures them by a few spikes. It is usually specified that the rails must be laid with the maker's brand on one side (usually outside) of the track. If the rails are bent or kinked in handling they should be straightened before being laid, and all rails curved in a rail-bending machine for curves of over 2° or 3°. Care must be taken not to let the joints run ahead, but to keep them truly square, or else exactly opposite the middle of the opposite rail, according to whether track is laid with square or broken joints. To maintain this even spacing, some of the inner rails must have pieces cut off. A good plan is to have a number of rails cut to a length of 29 ft. 6 ins. at the mill, these short rails having their ends painted so that they can be readily distinguished. These rails are kept separate from the regular 30-ft. rails, and a certain supply of them is carried on the material train. The foreman of the tracklaying gang should then be provided with a list of the curves and the number of short rails required on each curve.

The joint or splice gang then bolts up the rail joints, and the spiking gang sets the rails to gage and completes the spiking. In this latter work the rails on the line side of the track should be spiked first, and used as the gage rail, and in all cases the outer spikes should be driven in the forward side and the inner spikes in the rear side of the tie. About 75 to 80 men

would be required to lay a mile of track per day by this method. Greater progress is expensive, unless the ties can be hauled a long distance ahead with teams and properly distributed. By distributing them far ahead, however, the joint ties are likely to require shifting when the rails reach them. The engineer should see that the proper widening of gage is given on curves (see "Gage" in Chapter 18). In bolting up the joints the specified spacing must be strictly adhered to, and only iron spacing shims should be permitted. The width of such spacing will be found in the chapter on "Rails." During this work care should be taken to see that spikes, bolts and other small material are not lost or wasted. Any necessary tamping or filling under the ties is then done, and the ballast trains are then run upon the track and unloaded, and the ballast is put in place and tamped. Then comes the final lining, surfacing and dressing (described more fully in the chapter on "Maintenance Work"), the amount of care bestowed upon which depends upon the character of the road, but for first-class track, of course, all this will be carefully done. As few trains as possible should be run over a partly ballasted track, so as to prevent surface kinking of the rails, a defect which it is almost impossible to remedy subsequently. For this reason, the full tamping of the ballast should be carried on as each train load of ballast is distributed.

At sidetracks, the switches and turnouts must be carefully laid out, and substantially supported on a good bed of ballast. The center stakes should be set for sidetracks, and the positions of head blocks indicated. The turnout curve may be laid out with a transit, or by means of a tape, with calculated offsets from the main track, as described in the chapter on "Switch Work." On bridges and trestles, where the ties are drift-bolted or otherwise secured to the stringers, the track centers may be marked by tacks at intervals of about 20 ft., and offsets made at the distance to the edge of the rail flange. A chalk line is then struck between these offset points, and in tracklaying the gage rail is first laid, with its edge set to the chalk line, and is then securely spiked, the other rail being set in position by the track gage.

A convenient arrangement is to have a gang of 55 men in charge of two foremen, and equipped with three rail cars, one horse and two portable turntables. One turntable is placed at the loading and the other at the unloading end of the track. An ordinary load for the rail car is six rails, and a full supply of ties, splice bars, bolts, nuts, washers and spikes for that number of rails. If the driver reaches the front before the unloading gang has unloaded all the material from the first car he puts the turntable in position ready to haul the car off when empty, but if the gang finishes unloading before he arrives it runs the empty car off, ready to be hauled back. On returning to the loading end with the empty car, the driver puts the turntable on the track, and runs the car off onto a pair of ties. He then hitches the horse to the loaded car and goes to the front, while the loading gang runs the empty car back into position for loading. With such a gang of good men under a smart foreman a mile of track may readily be laid in two days. The distribution of the men is as follows:

9 loading truck from construction train.
8 unloading truck at head of track.
1 with horse hauling the truck.
4 Spacing ties and lining them with a cord.
6 Splicing joints.
27 spiking (3 sets of 9 men each).

The cost of tracklaying and surfacing (exclusive of ballast and ballasting) varies, of course, with the locality and the character of the track, but on Western roads it has averaged $250 to $500 per mile. One of the lowest records was that of the Atchison, Topeka & Santa Fe Ry., in 1888 ("Engineering News," May 25, 1889), when tracklaying at the rate of two miles per day was done with a gang of 164 men, at $170 per mile for tracklaying labor proper, and $60 per mile for surfacing, with a gang of 84 men; the total cost per mile, including expenses for engineers, engine and train crews, etc., was $248. Tracklaying on the Western Division of the Canadian Pacific Ry. was commenced June 1, 1882, and by Dec. 1 there had been laid 388 miles of main track and 30 miles of side track, west of Brandon. The greatest length laid in one day was 4.1 miles, and on three occasions four miles were laid in a day. The best speed on record was half a mile of track laid in 35 minutes. The rate of progress was as follows:

Month.	Working days.	Miles. Total.	Miles. Pr day.
June	26	68.70	2.64
July	26	63.56	2.44
August	27	86.86	3.22
September	26	71.25	2.74
October	26	59.38	2.28
November	26	38.30	1.47
Total	157	388.05	2.47

The tracklaying gangs on the Canadian Pacific Ry., where fast work was done, were composed as shown in Table No. 17:

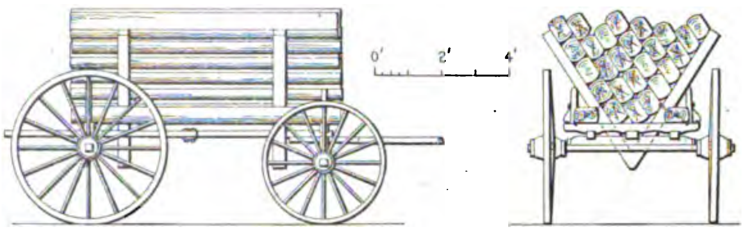
TABLE NO. 17.—TRACKLAYING GANG; CANADIAN PACIFIC RY.

Unloading rails from cars*	12
Loading rails on trucks*	12
Unloading and laying down rails*	24
Bolters	15
Spikers	32
Nippers	4
Spike peddlers and tie loaders	32
Teams hauling ties	33
Unloading and distributing ties	8
Spacing ties	4
Readjusting displaced ties	2
Rail truck boys (to 6 horses)	4
Total	182

*Eight men in each of these gangs were handling joints, bolts, etc.

The following is a detailed description (taken from an article written by the author and published in "Engineering News," New York, Nov. 14, 1895) of the train and methods of work employed in 1892-1893 in the construction of the extension of the Minneapolis, St. Paul & Sault Ste. Marie Ry., from Valley City, northwest across North Dakota, 263 miles, to connect with a branch line which the Canadian Pacific Ry. was then building southeast from Pasqua (on the main line) to Portal, on the United States boundary, 160 miles.

The track is laid with 30-ft. rails, weighing 72 lbs. per yd., spiked to cross-ties 6 ins. thick, 7 to 10 ins. wide and 8 ft. long, spaced at the rate of 2,816 to 2,992 per mile, or 16 to 17 per rail length. The rails have square three-tie supported joints, spliced by 40-in. angle bars with six ⅞-in. bolts, spaced 6, 6½, 7, 6½ and 6 ins. c. to c. The engineer did not approve of this joint, and questioned the utility of any splice bar exceeding 22 to 26 ins. in length. On the older track, south of Valley City, the track has suspended joints, with joint ties 7 ins. apart between faces, and the rails spliced by 23-in. Samson angle bars, with four bolts spaced 4½, 7 and 4½ ins. c. to c. The width at subgrade is 16 ft. The tracklaying and surfacing were done by the railway company.



Side Elevation. End Elevation.

Fig. 194.—Tie Wagon.

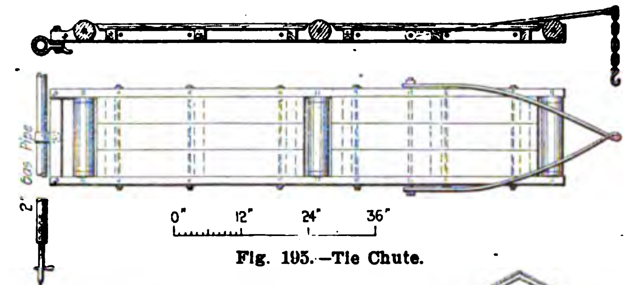
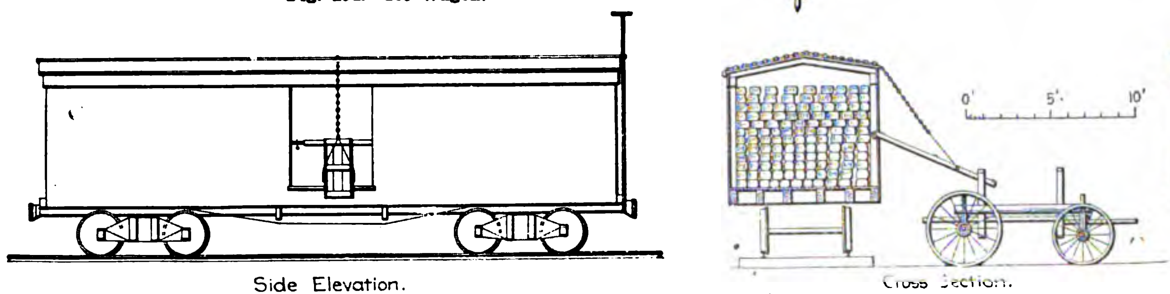


Fig. 195.—Tie Chute.



Side Elevation. Cross Section.

Fig. 196.—Unloading Ties by Chute.

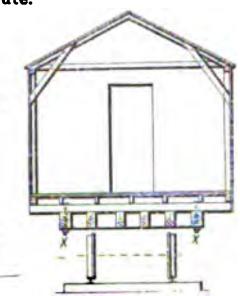


Fig. 201.—Kitchen Car

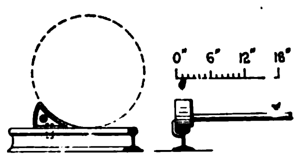


Fig. 199.—Stop Block for Rail Car

Fig. 198.—Tracklaying Gage.

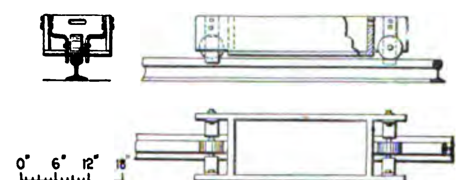


Fig. 200.—Spike Peddler's Car.

TRACKLAYING APPLIANCES ON THE MINNEAPOLIS, ST. PAUL & SAULT STE. MARIE RY.

The entire construction train was made up of 32 cars, as follows:

1. Pioneer car.
2. Store car.
3, 4. Dining and sleeping cars.
5. Kitchen car.
6. Dining and sleeping car.
7. Feed car.
8. Water car.
9 to 16. Flat cars with rails and spikes. Locomotive.
17. Telegraph material.
18 to 32. Box cars with ties.

Cars No. 1 to 8, both inclusive, formed the boarding or work train, which was always kept at the head of the track. The material train, composed of cars Nos. 9 to 32, both inclusive, was brought up during the night from the last sidetrack, and stopped so that the interval between cars Nos. 8 and 9 was about 400 ft. The tie cars, Nos. 18 to 32, were then cut off at the coupling between Nos. 17 and 18, and the rail and telegraph cars were moved up and coupled to the boarding train, making the train as described.

Work commenced at 7 a. m., the teams then beginning to haul ties from the five rear cars onto the grade (which had a top width of 16 ft.), where the tie men helped to unload, place and space them. The tie wagons are shown in Fig. 194, and the chutes for loading them with ties from the box cars are shown in Figs. 195 and 196. One hundred rails and the necessary fastenings were unloaded from both sides of cars Nos. 15 and 16, dropping onto the soft earth of the roadbed, and the train then moved back

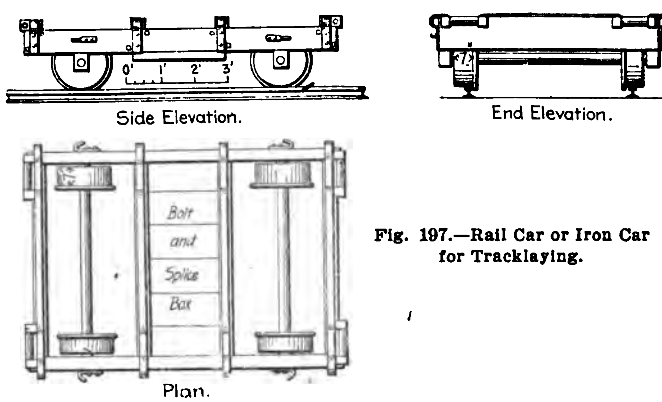


Fig. 197.—Rail Car or Iron Car for Tracklaying.

400 ft. The rails were handled by means of rail forks, Fig. 172. The 100 rails were then loaded on two iron cars, Fig. 197, each carrying 50 rails, and being "trimmed" with splice bars, bolts and spikes. The iron cars were then hauled to the end of the track by horses. Ten men on each side of the leading iron car ran forward with a rail and dropped it in place, together with a pair of splice bars and six bolts for each joint. Immediately the rails were dropped, one man threw a hook gage, Fig. 198, over them, near their outer ends, and the horse then pulled the car forward 30 ft., one man on each side stopping and blocking the car wheels with an iron stop block, Fig. 199. Two more rails were then quickly run out and dropped, as before. At every fifth and sixth rail length, alternately, a 200-lb. keg of spikes was thrown off, containing about 375 spikes 9-16 × 5½ ins. These kegs were broken open by the two spike peddlers, who took 100 lbs. of spikes in their car boxes, Fig. 197, and placed two spikes on each tie where it was crossed by a rail.

The tie-wagon, Fig. 194, was a four-wheel wagon, with two V-shaped supports to hold the ties, the capacity being about 25 ties. The tie chute, Fig. 195, was a plank platform with three rollers; the inner end was attached to a transverse bar of 2-in. gas pipe, placed at any desired height across the car door and secured by turning the pointed screw at one end; the outer end was supported by an iron sling and chain from the roof of the car. Fig. 196 shows the method of attaching and using the chute. The iron car, or rail car, Fig. 197, had two longitudinal sills and four transverse sills, with planks nailed across the bottom of two of the latter to form a box for splice bars and bolts; the wheels were 20 ins. diameter and 7 ins. wide on the tread, and two rollers were fitted at each end in the usual way; each car could carry 50 rails of 72 lbs. per yd. The hook gage, Fig. 198, was used to hold the free ends of each pair of rails as laid, while the iron car was run onto these rails and stopped by the block shown in Fig. 199. The spike peddlers' cars, Fig. 200, was a handy little device, running on one rail and carrying about 100 lbs. of spikes, so that the spike peddlers could distribute the spikes very rapidly. The double-deck dining and sleeping cars were 34 ft. long over the body with a 3-ft. platform at one end; the width of the body was 12 ft., out to out, and the dining room and sleeping room had each a clear headway of 6 ft. 3 ins.; the sleeping room had two rows of berths on each side. The kitchen car, Fig. 201, was of similar dimensions, but had only one floor. In both of these cars the bodies could be removed by unbolting the four corner bolts, X X, which secured the end floor beams to the outer sills of the car frame.

The two "front strappers" put on the splices, adjusted the expansion spacing by metal shims, and fastened the two center bolts, the other strappers following and completing the joints. Four "front spikers" with a gage followed close on the front strappers, and spiked the track at joints, centers and quarters, while 12 other spikers finished the spiking. For each two spikers there was an assistant, called a "nipper," who held the tie up to the rail with a nipping bar, using a block as a fulcrum. When the rails on both iron cars were nearly all in place, the train was again run forward, and 100 rails and the necessary fastenings thrown off as before, and the train again run quickly back out of the way. The iron-car gang would "drop" 100 rails (1,500 ft. of track) in from 25 to 30 minutes. The cars were brought forward at about every second move of the train, or oftener if the nature of the ground required it.

At about 11:30 a. m., the ties remaining in the box cars were thrown out on the ground, to be picked up and loaded on the wagons, while the empty cars, Nos. 9 to 32, both inclusive, were run rapidly back to the nearest side track and exchanged for loaded cars arranged as before, these being brought to the front in time for work at 1 p. m. An additional locomotive, pushing at the rear of car No. 32, was employed when the grades required it. Telegraph material was thrown off car No. 17 at each forward movement of the train. The poles were of cedar, 6 ins. diameter at the small end and 25 ft. long, set 5 ft. in the ground, and these were spaced 30 to the mile. The wire was stretched from a reel placed on a small hand wagon, pushed by men. Tents were carried on the boarding train to be set up at night for quarters for extra men, or to shelter the horses in cold weather. Detachable feed boxes were slung on the sides of the boarding cars. The

general foreman had control of all trains and employees working at the front, and in case of emergency could at any time communicate by telegraph with the superintendent of construction, a few miles at the rear. Material tracks from 2,000 to 2,500 ft. long were laid at intervals of about 10 miles, unless regular stations were to be provided at shorter distances.

Surfacing gangs, who lived in boarding cars set off on temporary side tracks, followed the tracklayers, and surfaced the track from the shoulders of banks or sides of cuts, so as to make a safe roadway and prevent bending of the rails or splices before the ballasting was done. These gangs usually numbered 40 to 45 men under a foreman and sub-foreman. About 250 men were required, and they went to and from work on hand cars.

Mr. Rich, the Chief Engineer, stated that the company had laid much track with several of the tracklaying devices in use in this country, and in swampy, very hilly, or timbered regions they were very serviceable, but in a dry, open country, like North Dakota, the method above described enabled the work to be advanced at double the speed and at no greater cost per mile. The average advance was three miles per day, and on one or two occasions in 1893 over four miles of track were laid in 10 hours with the force named below, and by increasing the force without regard to strict economy, five or six miles might be laid in a day.

The entire work was in charge of a superintendent of construction, stationed at the siding nearest to "the front," or the head of the track, who ordered and forwarded material and gave general instructions. He had a business car, a clerk (who was also a telegraph operator), and a cook. The telegraph line was in working order at the end of the track every night, the instrument and operator being located in car No. 1. The tracklaying force was as given in Table No. 18.

TABLE NO. 18.—TRACKLAYING FORCE; M., ST. P. & S. S. M. RY.

	Foremen.	Laborers.
General foreman, on horseback	1	..
Iron car gang (who dropped rails and fastenings)	1	22
Strappers (who adjust and bolt splices)	..	6
Spike peddlers (distribut. spikes)	..	2
Tie-spacing gang	1	12
Men lining ties (rope & stakes)	..	2
Men spacing joint ties (with 30-ft. pole and tie pick)	..	2
Men leveling grade cut by tie wagon	..	4
Spikers	..	16
Nippers (hold up ends ties for spikers with blks & nip'g brs	..	8
Tracklining gang	1	6
Teamsters for the wagons	1	40
Men unloading ties from cars (3 to each car)	..	15
Men unloading rails and fastenings from cars	..	4
Telegraph gang	1	8
Telegraph operator	..	1
Drivers of iron-car horses	..	2
Blacksmith	..	1
Night watchman	..	1
Cooks	..	2
Baker (worked only at night)	..	1
Waiters and helpers	..	5
Storekeeper	..	1
Total	6	161

All baking of bread and pastry was done during the night by an extra force of cooks. The cooks, baker, waiters, helpers and storekeeper were employed by a contractor, who boarded the men for $3.50 per week, furnishing all supplies and bedding. The amount for board was deducted from the wages of the men and paid to this contractor.

Returning to the details of the train and equipment, the make-up of the entire train has already been described. The equipment and capacity of the boarding train, kept at the head of the track, was as follows:

No. 1. Pioneer car, double deck. This contained a blacksmith shop, 10 × 12 ft.; storeroom, 8 × 12 ft., for heavy tools, harness, etc.; office for general foreman, 12 × 14 ft., with three sleeping berths and telegraph office; two sleeping apartments on the upper floor, and a tool box under the car. In front of the car was a platform supported by rods from the top, carrying extra splice bars, bolts, and spikes, and under the platform was fastened an extra iron car for emergencies.

No. 2. Store car, double deck. This had a storeroom for clothing, shoes, tobacco, etc., and another for provisions; sleeping berths for the cooks, a sleeping apartment above and a tool box underneath.

No. 3. Dining and sleeping car, double deck. On the lower floor were two dining rooms, one for the foremen and guests, the other for teamsters and telegraph gang. Above were separate sleeping apartments for the teamsters and the telegraph gang, and underneath was a tool box.

No. 4. Dining and sleeping car, double deck. On the lower floor was the laborers' dining room, and above was a sleeping apartment, with berths for 32 men. Underneath was a tool box.

No. 5. Kitchen car. This had a kitchen and provision room, 12 × 32 ft., with two cooking ranges. Underneath was a water reservoir supplied by hose from the water car (No. 8), while pumps in the sinks delivered the water as needed by the cooks. This car had no upper deck. (Fig. 201.)

No. 6. Dining and sleeping car, double deck. On the lower floor was a laborers' dining room, and on the upper floor was a sleeping apartment with berths for 32 men. Underneath was a box for wood for fuel.

No. 7. Feed car. An ordinary box car, 8 × 34 ft., carrying feed for the horses and coal and wood for the use of the cooks.

No. 8. Water car. A flat car, having at each end a wooden tank of 2,000 gallons capacity, the tanks being connected by a pipe.

No. 9. An ordinary flat car, loaded with rails, bolts and spikes.

No. 10. (Car No. 17). An ordinary flat car, loaded with telegraph material.

In the extension of the Atchison, Topeka & Santa Fe Ry. from Stockton, Cal., to Point Richmond, some rapid work was done, as noted in Table No. 19. The rails were laid with broken joints, and there were 17 ties per rail on tangents, 18 on curves up to 3° and 19 on curves over 3°. The first piece of work was practically level; the second had a descending grade of 1%, with curves at intervals of ½ mile.

TABLE NO. 19.—TRACKLAYING; A., T. & S. F. RY.

Date	Oct. 9-25, 1899.	Feb. 20, to Mar. 30, 1900.
Track laid	10.74 miles.	16.6 miles.
Average per day	2,846 ft.	3,503 ft.
Maximum per day	5.400 "	4,500 "
Rails	62½-lb.	75-lb.
Number of men, average	44.6	47.9
Number of men for maximum day's work	57.0	52.5

Foreman	1	Distrib. spikes	1
Sub-foremen	3	Spacing ties	2
Strappers	4	Spacing rails	2
Iron car men	10	Back bolting	2
Spikers	8	Tie carriers	2
Nippers	4	Picking up material	1
Tie line man	1		
Lining ties	2	Total	52
Tie plater	1		

The boarding outfit was spurred out to one side. The tracklaying train carried out each morning enough material for one mile of track, made up as follows: Pioneer car, 3 cars of ties, 2 cars of rails, 3 cars of ties, 2 cars of rails and the tool car. The train was pushed to the front, a certain amount of rails and ties unloaded, and the train then pulled back. The material was then loaded on iron

cars or push cars, the rails ahead and the ties behind. The ties were carried around the rail car and distributed, after which the rails were thrown in place and the rail car and tie car moved forward, this being repeated until the loads on the iron car were exhausted. Strappers and spikers followed the iron cars and partially spiked and bolted the track before the train came upon it. As soon as the material unloaded from the train was laid, the train was again pushed forward and another lot unloaded. The iron cars were pulled forward by a single horse. The track was laid with ties which had been tie-plated in the material yard before being sent to the front. The tie-plates under the joints had spike holes punched to a different spacing from those used elsewhere under the rail, and as the track was laid, it was necessary for a man to attend to taking out the ordinary plates and replacing them with the joint plates. He also had to replace any plates which might have shaken out during transfer to the front. This was the duty of the "tie-plater." The rails were all curved in the yard before being forwarded to the front. The iron car men attended to unloading the rails from the flat cars and loading them on push cars. They also handled the fittings, such as splices and spikes, until it came to distributing, when an additional man was used for distributing spikes. The men who handled the rear end of the rail were known among the track men as "heelers." They unloaded from the iron car the splices at the proper places. The surfacing was done by a following gang taking material from the corners of the bank, throwing it between the ties and using it for tamping. In some cases, however, material such as sand for surfacing purposes was hauled onto the track, there being no ballast which could be obtained at hand.

Tracklaying by Machinery.

Tracklaying machines are now very extensively used, not only on large railway contracts, but also on lengths of 50 to 100 miles. For long stretches of work and in difficult country (rugged or swampy), especially where teams cannot be used to distribute the ties ahead in the usual way, machine tracklaying is very extensively employed and permits great rapidity, with a saving in cost over the ordinary method. It is also preferable in laying new track, as it avoids the cutting up of the roadbed by teams hauling ties. The title "tracklaying machines" is rather incorrect, since the machine does not lay the track, the general principle of the system being that the ties and rails are run to the front of the supply train on rollers or tramways laid along the cars, and are delivered to the tracklaying gang from a frame projecting in front of the first or pioneer car, this car or "machine" forming the head of the material train, which is pushed forward as fast as the track is laid, moving one or two rail lengths at a time. The supplies for a day's or half a day's work are carried on the material train and delivered right where wanted, the train being moved up 30 or 60 ft. at a time, according to whether the rails are laid singly or in two-rail lengths. It is not uncommon practice to lay only half the number of ties to a rail length ahead of the train, leaving the rest to be put in by a tie gang following the train, thus somewhat reducing the close work of a large gang, but while a single train may perhaps not do very much damage to a half-tied track, it is, as a rule, better practice to put in the full

number of ties before the train runs over the track. There will then be less liability of injuring the rail or joints by surface kinking.

The speed depends largely upon the ability to keep the machine supplied with material. On the Rio Grande, Sierra Madre & Pacific Ry., in 1897, the work averaged 2¼ miles per day, and could have been increased to 3 miles if material had been supplied, but in this case teams were used in addition to the machine. It is possible with iron cars or rail cars to put on enough men to lay more track by hand than by machine, but this is more expensive and it is very difficult to regulate the expansion, as one strapper will steal from the next one, and the rails are dropped so carelessly for long stretches that bolts can hardly be got in. The gaging and spiking are also done hurriedly to let the train come up, and under this system, generally speaking, the track is "dropped down" rather than "laid." Such rapid work is now rarely necessary, as with the completion of the great transcontinental lines the time has passed when speed in laying was the main consideration.

The Holman tracklaying machine, Fig. 202, is composed of a series of tramways 30 ft. long and about 20 ins. wide, fitted with heavy iron rollers, and these tramways are attached to the sides of ordinary flat cars, without any changes, being supported by adjustable iron stakes that fit into the pockets on the sides of the cars. The sections are connected and operate the full length of the train, as continuous inclined tramways. The ties and rails on the supply cars are thrown upon these tramways and rolled down to the front, where men receive and place them in position on the roadbed. The ties come down on one side of the train and the rails on the opposite side. The tie tramway ends in a chute, supported by a wire cable, which runs out 35 ft. in front of the train, so that the men handling the ties are one panel ahead of the rail men, and consequently the gangs are out of each other's way. As each rail comes down the chute it is seized by the rail men, placed on the ties and pushed back against the end of the last rail, the expansion spacing being arranged by the joint gang.

The pioneer or pilot car at the head of the train is fitted with an elevated frame or trestle, from which the chutes forming the end of the tramways are suspended, and on this frame rides a brakeman who signals the engineman when to push ahead, and attends to the brakes on this car. The splice bars, bolts, and spikes are carried on the pilot car. A train of ten cars (six cars of ties, three cars of rails, and the tool car) will carry all the material required for a half-day's work and from half to three-quarters of a mile of track. From 1¼ to 1½ miles of track per day can be laid with this machine, or even 2 miles with from 40 to 60 men, provided the railway company can deliver the material at the front fast enough, and in proper shape. This includes the full supply of ties, laying the rails in position; joint, quarter and center spiking; putting on the fish-plates or angle-bars, and putting two bolts through the same. This leaves the track in safe condition for the construction train to pass over, and the balance of the work is finished behind the train without reference to or use of the train. As fast as the panels or rail lengths are laid, the train moves forward 30 ft. at a time, carrying all material with it, leaving nothing scattered along the line.

In the construction of 120 miles of the Washington County Ry. (Maine) in 1899, with the Holman machine, the largest amount of track laid in any

one day was 10,300 ft., fully tied and spiked; this was laid in 9 hours with 110 men. Two train loads of material were usually laid each day, the trains consisting of about three cars of ties and three cars of rails. The first train was taken out in the morning, and it was usually arranged to have the

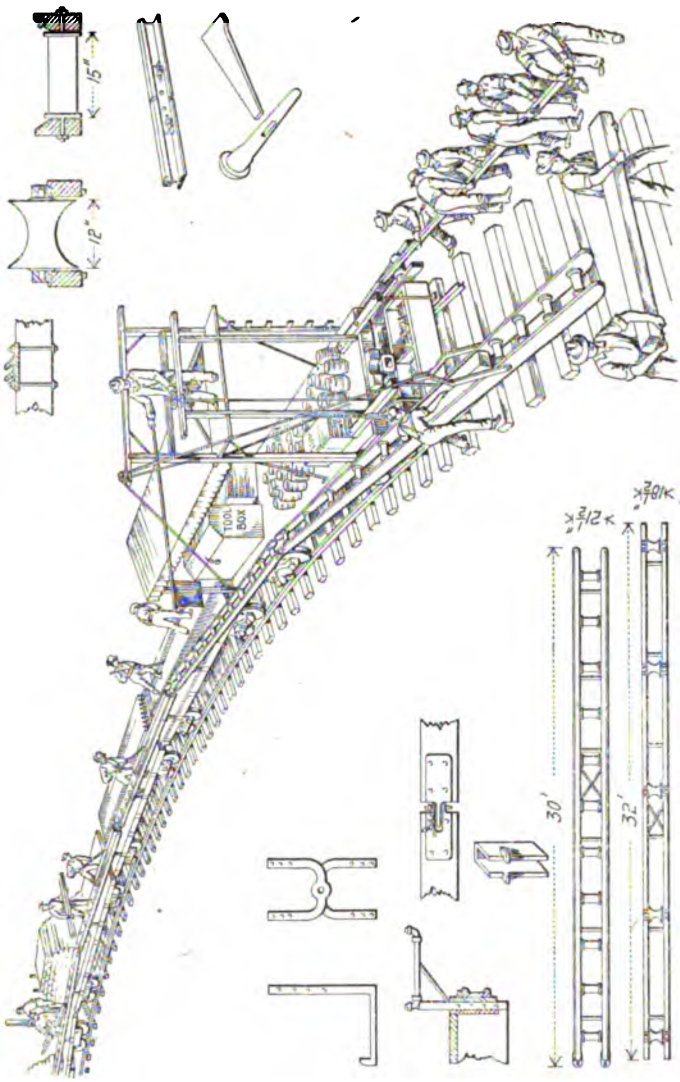


Fig. 202.—The Holman Tracklaying Machine.

second train at the nearest siding at noon, when the trains were exchanged. The ties were distributed about two rail lengths ahead of the rails, and the full number was always laid, as it was considered that with machine work it was cheaper to do this than to put in only half the ties in front and to

lay the rest behind the machine. There were usually about 90 men in the gang, distributed as follows: 26 running ties out; 3 running rails out; 8 receiving and placing rails at the front; 6 carrying ties to the front; 2 lining; 2 bolting up splice bars; 30 spiking; 4 lining and spacing ties, and 6 helping, waiting on the others, etc.

The Burlington & Missouri River Ry. has laid its own track for the last eight years, and its last contract for tracklaying by hand, before that time, was let at $300 per mile, which included loading track material and higher wages than these now ruling. Both the Holman and Harris tracklaying machines have been used, and the former was used on the Billings extension, built in 1894. According to Mr. I. S. P. Weeks, Chief Engineer, the speed of the Holman machine, with a force of 85 men, was 1½ miles per day, which is the most convenient speed, and the cost at such rate was about $100 per mile. For this rate there was a morning and an afternoon train, each made up of four flat cars of rails and four flat cars of ties ahead of the locomotive, and four box or flat cars of ties behind the engine. On the Billings extension the track was laid with 65-lb. rails, and 18 ties to a rail, or 3,168 ties per mile. The track was half-tied in front of the engine, the balance of the ties being put in by lifting the rails and dragging the ties into place endways. Curves of 1° to 16° were laid without any special arrangement. Mr. Weeks stated that, if it should be desirable to lay 2½ miles of track per day, it could be done by working two shifts of men with the Holman machine, laying 1¼ miles each in the morning and afternoon. With the Harris machine, he has laid 2½ miles per day on a spurt, when ties were distributed ahead of the track. This machine has been used with very satisfactory results, and at about the same expense as the Holman for a rate of 1½ miles per day. With the Holman machine there were 86 men, distributed as shown in Table No. 20:

TABLE NO. 20.—TRACKLAYING GANG WITH HOLMAN MACHINE; B. & M. R. RY.

43 Men in Front of the Engine.		43 Men Behind the Engine.	
1 foreman,	1 line man,	1 straw boss,	2 spike peddlers,
1 heeler,	1 poleman and marker,	2 tie unloaders,	4 bolters,
4 spikers,	4 tie carriers,	2 tie placers,	1 gage carrier,
2 nippers,	2 tie spacers,	4 tie spacers,	1 water boy,
1 rail thrower,	1 tram tender,	2 rail lifters,	2 spike pullers,
1 spike peddler,	1 bolt trimmer,	12 spikers,	4 liners.
1 gage carrier,	2 bolters,	6 nippers,	
1 expansion driver,	2 strap carriers,		
2 fork men,	8 tie pushers,		
4 rail pullers,	2 tie loaders.		
1 water boy,			

With the Harris tracklaying machine ordinary 34-ft. flat cars are used, with four or five bridge ties, 6 × 8 ins. and 11 ft. long, laid across the floor, at proper intervals, and bolted to place. Ordinary ties are laid between them, and upon these is laid a track of 2 ft. gage. Fish-plates are attached to the ends of the rails by a single bolt through the end hole in rail, and end holes in plates, thus causing the plates on adjacent cars to project toward each other as far as possible. The gap in the track between cars is then filled by short rails, having 18 ins. of the base cut off at each end, to permit of dropping the web into the slots formed by the projecting plates attached to the ends of the fixed rails on each car. These connecting rails are cut short enough to avoid jamming when all slack in car couplings is closed up to the minimum. Ten pairs of the short rails will

equip a train of material, and they are always retained at the front, for use on each train while unloading. Along the middle of each car carrying rails are four or five iron rollers, 3½ × 10 ins., attached to the cross-ties along the deck of the car, forming a runway for conveying rails to the front. The rails are loaded in two neatly made piles, one on each side of the car, so as to clear the rollers in the middle and the tie car. Each car carries the proper complement of splice bars, stored in the open spaces between the cross-ties, while spike and bolt kegs are loaded in the runway between the rail piles and are afterwards moved to the end of the car, preparatory to unloading when the train reaches the front. The cars for the ties have the tramway, but no rollers.

The front, or "pioneer" car has, in addition to the rail rollers and tie tramway, a frame of stringers extending the tram track 15 or 20 ft. ahead of the car, the outer end being supported by truss rods fastened at the rear end of the car and passing over a gallows frame about 10 ft. high at the middle of the car. A stout cross beam on the ends of the stringer has a short timber projecting downwards and carrying a double ended roller about 2 ft. below the level of the car deck. This roller is about 14 ft. from the end of the car for laying single rails, or 22 ft. for laying two 30-ft. rails spliced together. Two portable "dollies" are used at intervals of 15 ft. ahead of the car. These are light trestle frames, about 3½ ft. high, each with a roller 4 × 18 ins. on the top. The 2-ft. gage car or tram for conveying the ties to the head of the train has a platform 5 × 9 ft., and is fitted with a double frame, so arranged that when the wheels stroke the chock blocks on the front end of the stringers, the top frame will slide forward about 3 ft. on rollers. This shifts the load forward, causing the car to tilt and dump the ties on the roadbed. The car then tilts back, and the men slip the top frame back into position while returning for another load. Owing to the length of the ties, the men on the rail cars have to move back onto planks laid on the ends of the 11-ft. timbers to allow the tie tram to pass. Another truck, with a single frame, is used to advantage in conveying the ties part of the way from the tie cars to the front, the load being transferred to the dump car at the meeting point. This plain car is run forward between two wooden horses (one on each side of the 2-ft. track), which are lower than the top of the car. The latter is then dropped so as to leave the ties supported on the horses. The dump car runs under this load of ties and automatically trips the top part of the horses, so that the ties drop onto the car. The tie trams and pioneer car are kept permanently at the head of the track, the car being coupled to each material train as it arrives. The machine can be used on sharp curves, and from 1 to 3 miles of track per day can be laid. For ordinary work the full number of ties may be laid in advance, but for fast work, half the ties are put in behind the train.

Material for a mile of track is loaded on 15 cars behind the pioneer car, as follows: Five flat cars with 72 rails each, 5 flat cars with about 300 ties each, and 5 (sometimes 7 or 8) box cars with about 1,500 ties in all. The engine is at the rear and pushes the train to the head of the track. The pioneer car is coupled to the front car of the train, the short connecting rails are adjusted in the tie-tram track, spike and bolt kegs are taken from the runway and stored on the ends of the cars, and the tie-tram is

run back and loaded. One man with a rail fork throws two rails from each of two of the rail cars onto the rollers, when four men pull these four rails forward to the pioneer car, two more men on the rear end of that car putting on the splice bars and two bolts, and putting in the expansion shims. The man on the rail car also throws off the splice bolts and spikes, as required. Meanwhile, 16 to 18 ties (for two rail lengths) have been loaded on the tram and the rail men step aside to let it pass, as it runs forward to dump its load on the ground, where the tie men distribute them over 60 ft. of roadbed. When the tram is run back, the four rails (bolted together in pairs) are run forward over the dumping frame rollers onto the portable "dollies" until the rear ends are clear of the car. The rails on the line side are then lifted from the rollers and dropped on the ties, thrown back against the rails already laid, and fastened to the latter by one bolt through the splice bars previously bolted to them. While the gage rails are being laid in the same way, 4 men are spiking the line side at 3 or 4 ties per rail (quarters and centers), and 4 more follow with gages and spike the gage rail. At the same time 2 men are putting expansion shims at the heel joints of the two-rail section and half-bolting up these joints and 2 more are putting the splice bars on the front end of the section, while others are moving the dollies ahead. A flagman near the front end signals the engineman when to stop and start, and the train is now moved ahead 60 ft., bringing the front end of the pilot car about 8 ft. from the end of the rail, when another load of ties is dumped as before.

Meantime, a few men in two of the box cars at the rear of the train drop off eight or nine ties per rail length at each move of train, while a man on the ground alongside sees that the ties do not go down the embankments, and also that no more or less than the proper number are dropped off. A few men with picks and four quick-working ratchet jacks follow immediately in the rear of the train, putting in the back ties, and those are followed by the back bolters, spikers and lining gang, who complete the work in the rear as fast as it is strung out at the front. In other words, track is only half-tied, half-bolted and quarter-spiked in front of train. Material to complete the work is distributed from the train as it advances, and the back gang keeps the work completed close up to the rear of the train. For laying track with broken joints, the ties are carried 15 ft. further ahead, and the four rails (two lengths of two rails each) are run out as usual. The line rails are dropped into place. The gage rails are run out 15 ft. further on the rollers of the dollies, then dropped into place and heeled back into the angle bars of the rails already laid. This is done while the line spikers are spiking their first tie, so that no time is lost, as the gage spikers start their work as soon as the gage rail is in position.

For quick work, two tie trams may be used when the front cars of ties are unloaded, the front one being the dump tram, and each load being transferred from one tram to the other. This plan, with a long train, is said to save two hours a day and to enable 2,000 ft. more track to be laid than with one tram. With this system of working, as above described, the organization of force for laying two miles of track per day on the Chicago, Kansas & Nebraska Ry., in 1887, was as follows:

On the train: 2 bolters, 4 or 6 rail pullers, 1 man throwing rails on rollers and dropping off bolts and spikes, 6 men handling ties and running

the tram (or 8 men with two trams); 13 to 17 men in all. In front of the train: 8 spikers, 4 nippers, 12 rail men, 2 bolters, 2 men moving the "dolly," 1 handling the tie line, 1 handling the 30-ft. pole and marking the ties, 1 spike peddler, and 1 water boy; 31 in all. Behind the train: 4 bolters, 12 to 14 men with two track jacks and some picks, pulling in and spacing the additional ties, 16 to 20 spikers, 8 to 10 nippers, 5 liners, 2 spike peddlers, 1 tie marker and 1 water boy, or 49 to 57 in all. The complete crew would consist of 1 general foreman, 1 heeler acting as foreman of the front gang, 1 foreman in charge of the back spikers, 1 foreman of tie gang, 1 sub-foreman lining track and 100 to 115 laborers. The tie markers carry a measuring board, which they place on the line end of every tie and strike a chalk line across, 16 ins. from the end of the tie, to guide the spikers in keeping ties in line.

With four quick bolters in front, easy-fitting bolts, and a well-trained front gang, a 60-ft. section was often laid in 2½ minutes for hours at a time, the train being moved up as fast as the men could handle the material. Owing to delays in switching and running to and from work, the force never worked 10 hours consecutively, but over two miles of track were usually laid in 9 hours' steady work, and some of the records were as follows: 1,300 feet in 30 mins., 5,600 ft. in 4 hrs. 5 mins., 11,100 ft. in 8 hrs. 30 mins., and 11,000 ft. in 8 hrs. 55 mins. It was estimated that over 12,000 ft. could be laid in 10 hours, at a cost of $240 for gang and foremen; adding to this the cost of motive power and trainmen and the expense of loading cars, the cost was estimated to be somewhat less than $150 per mile. The half-tieing is, of course, a disadvantage.

The Chicago, Rock Island & Pacific Ry. constructed about 1,300 miles of track with the Harris machine in 1886 and 1887, the results being satisfactory in point of cost, speed and quality of work. Mr. D. Sweeney, Division Roadmaster (who was in charge of the work on the C., K. & N. Ry., above noted), has given the following detailed particulars:

"It requires not fewer than 100 men to work this system to its full capacity, which is a little upward of two miles per day. The front bolters must be sufficiently expert to splice a joint with two bolts moderately snug in every 2½ minutes; failure on their part will delay the entire work. Rail pullers and tie-tram men must be lively workers, but the men on other parts of the work can keep up by moderate efforts. The average cost of laying two miles of track per day by this method is about as follows:

	Av. rate.	Total.		Av. rate.	Total.
1 general foreman	$5.00	$5.00	1 engine and train crew	$20.00	$20.00
2 assistant foremen	3.00	6.00			
109 laborers	2.00	218.00	Total for two miles		$249.00

"To this must be added a small amount per mile as royalty for use of the machine, and about $10 per mile for preparatory work in transferring material to the cars in the yard, all of which will bring the actual cost to about $140 per mile where work is properly handled and not subject to much interruption or delay.

"The Chicago, Rock Island & Pacific Ry. has also constructed about 200 miles of track with the Holman machine, during the past few years. This was done in a leisurely way and in short patches that did not justify equipping cars for the Harris system. The general work of the Holman system has already been described, but on the C., R. I. & P. Ry. the track was not full-tied ahead of the train. After 8 or 9 ties were delivered and spread on a 30-ft. section of roadbed, the rails were heeled to place, one at a time, and spiked to four ties, the train being then moved forward 30 ft. and the

process repeated. The back tieing and finishing up were done in the same manner as with the Harris machine. The average capacity of this system was about one mile per day with 60 to 70 men, which is about as many as it will employ to advantage. The following is an approximate cost of work per day:

	Av. rate.	Total.
1 general foreman	$5.00	$5.00
2 assistant foremen	3.00	6.00
70 laborers	2.00	140.00
1 engine and train crew	$20.00	$20.00
Total for one mile		$171.00

"It will be seen here that it cost as much for train and foremen in laying one mile with the Holman as it does to lay two miles with the Harris. Still, the Holman is the more economical for short stretches, or in cases where tracklaying is subject to frequent delays awaiting material, or the completion of grading and bridges. The gang is comparatively small, has few places requiring specially trained men, and would be subject to little loss or demoralization in changing from tracklaying to surfacing, and vice versa. It is probably that the capacity of the Holman machine could be largely increased by making slight changes in the machine and method of working it. But either of these machines will lay track more economically than it can be done with iron cars. The system does away with the heavy expensive team work and cutting up of the roadbed incurred in hauling ties ahead of the track. It also prevents leaving large piles of surplus material scattered behind the tracklayers to be afterwards picked up at considerable expense, or else wasted.

"The following is an approximate estimate of force and expense in laying track at the rate of two miles per day by the old style iron car method:

	Av. rate.	Total.
1 general foreman	$5.00	$5.00
5 assistant foremen	3.00	15.00
160 laborers	2.00	320.00
22 teams hauling ties	4.00	88.00
1 team hauling iron cars	$4.00	$4.00
1 engine and train crew	20.00	20.00
Total for two miles		$452.00

"Of course the expense in all methods will vary in accordance with the rate of wages allowed to employees, and each method must have sufficient force to work it to its maximum capacity in order to attain the best results."

The special feature of steam tracklaying machines is that the material is run to the head of the train on tramways having rollers operated by steam power. The Roberts machine consists of a head or "pioneer" car fitted with side chutes for delivering the rails and ties on the ground ahead of the train, and having a stationary steam engine to operate the rollers in the chutes. Similar chutes or tramways extend along each side of the flat cars of the material train, being carried by brackets inserted from the bottom of the stake pockets. They are connected between the cars, and in the bottom of each chute are live rollers, the alternate rollers being driven by a shaft extending the whole length of the train and being fitted with universal couplings between the cars. The vertical engine on the head or pioneer car drives the shafts by means of gearing, and takes its steam from the locomotive. The rails are sent forward on one side of the train and the ties on the other, the ties being delivered by the chute about 60 ft. ahead of the rails, while the rail chute extends about 6 ft. beyond the car. The driven rollers of the tie chute have corrugated surfaces, to get a good hold on the ties, while the alternate rollers are plain, and are set about 1 in. lower than the others. The material train is made up with the rail cars in front of the locomotive and the tie cars behind.

In laying track on the Columbia & Western line of the Canadian Pacific Ry., in 1899, a Roberts machine was used. At the material yard 8 men and

a foreman were employed in unloading, sorting and reloading rails and fastenings, and in curving rails. Each car sent to the front with rails was numbered with a consecutive or lot number, and also marked with the initial station of any curved rails it carried, the first and last rail of each curve having the station painted on it. The cars of rails loaded for the front were trimmed with angle bars only. Spikes, bolts, tie-plates, etc., were loaded together in a separate car, which was used as a tool car, as noted below:

The tracklaying train was made up for half a day's work as follows: (1) The pioneer car; (2) four cars of rails carrying 1,000 ft. of track and angle bars, or about 22 tons; (3) the engine; (4) eight cars of ties carrying 250 to 270 ties each; (5) the tool car. A pushing engine was used at the rear when required. The angle bars and some bolts were transferred to an apron on the front end of the pioneer car. The tracklaying force proper was distributed as follows: (1) The tie-line stretcher, whose duty it was to keep the tie-line stretched 4 ft. from track center stakes as a guide by which to line up the ends of the ties; (2) eight or ten "tie buckers," who took the ties from the end of the tie tram or chute (which extended about 60 ft. beyond the pioneer car and dropped them approximately at the required spacing; (3) the tie marker, who marked ties where rails should lie across them, and kept the spacing "pole" moved up as required; this pole was a piece of band iron 30 ft. long, with a ring in the front end to pull it along and having copper rivets at intervals to mark the proper spacing of the ties; it was placed just outside of the tie line; (4) two men with "picaroons" lining the ties to the tie line, and at the same time squaring and spacing them according to the rivets in the "pole." All this work was entirely ahead of the steel or rail gang and out of their way.

The steel gang consisted of 8 "heelers" and 2 "strappers." The strapper put a pair of angle bars on the last rail laid, and one bolt, not yet tightened. When the next rail came he opened the angle bar with his wrench to receive the rail end. The rail was "entered," the front end dropped and rail pushed back against the expansion shim, the bolt tightened up, and bolt struck and nut started for rail just laid. This is called the "slow heel" method, but is believed to be just as quick as and to give a better chance to regulate the expansion than the common method of throwing each rail back against the one laid. By the time the first bolt is tight the conductor signaled the engineman to move ahead, and the train advances a rail length. No spiking at all was done ahead of the train. The rails were held to gage by bridle bars, two to a rail length on tangents and three on sharp curves. These bridles were ⅝-in. rods, flattened at the ends and turned back so that the rails were at proper gage when the bridle was hooked under the base of the rails. There was a slot through it at the inside edge of the rail, through which a spike was stuck. The bridle was hooked under the line rail, a spike dropped in the slot, and the gage rail thrown in so as to clear the turned over part of the bridle; the bridle being held up and the rail pushed out it hooked itself, and on the spike being dropped in it was secured. The bridles were put on by the "heelers," who generally got them on before the "strappers" could fix their joint.

On the "pioneer car" there was the engineman for the stationary engine

that ran the tram rollers, and one of the train crew to give signals to the locomotive engineman by means of whistle signals from the stationary engine. There were 3 men on the tie cars throwing ties into the trams or chutes with "picaroons;" 1 man on the tool car dropping off bolts and tie-plates, and 2 spike peddlers distributing spikes for each tie. The back gang consisted of 2 men lining, spacing and squaring any misplaced ties, taking off the bridles, and putting the tie-plates under the rails; 1 man picking up bridles and sending them to the front in a long narrow box over the tie trams; four or six gangs of spikers (each consisting of 2 spikers and 1 nipper), and finally two back bolters.

This force would lay a pair of rails per minute, or sometimes a little better. It averaged 1,000 ft. of track per hour, and always had to lay the four cars of steel, besides putting up and taking down the tramways or chutes before stopping for dinner. They would do the same in the afternoon. The night crew did the switching at noon, making up the material train for the afternoon, and at night brought up the loads required for the next day. Ordinarily camp cars and stock of material were within 10 miles of the front. Ample motive power was necessary, as the train must be able to start quickly at each move. Two medium consolidation locomotives proved rather slow for handling the 14 loads on a grade of 2.2%. No cars without air brakes should be loaded for the front. The train equipped with the Roberts appliances would work on curves of 14°, but not on a temporary curve of 22° on which it was tried. With the new Roberts tie distributer and two gangs of heelers, the machine will lay twice the amount of track, and the train need never come to a full stop.

The Roberts machine was used in 1894 on the Chicago & Eastern Illinois Ry. between St. Elmo and Mount Vernon, Ill., laying 60-lb. rails and 2,815 ties per mile. The average speed was two miles per day, and the highest was one mile in 2 hrs. 50 mins. The distribution of the force is given in Table No. 21:

TABLE NO. 21.—TRACKLAYING WITH ROBERTS' MACHINE; C. & E. I. RY.

36 Men with the Train.	44 Men Behind the Train.
3 foremen,	4 men distributing splices and spikes,
1 engineman on machine,	4 back strappers,
4 men loading ties on trams,	16 back spikers,
2 men loading rails on trams,	8 back nippers.
7 men placing rails,	1 oiler,
8 men placing ties,	5 lining track,
4 head spikers,	6 spacing ties.
3 head nippers,	
3 head strappers,	
1 tie liner.	

Ballasting.

For a new line, the ties are placed upon the subgrade, and when the rails have been laid, the ties are tamped with earth and the track is lined and surfaced to make it safe for the ballast trains to run without injury to the rails or joints. In some cases, however, the track is jacked and blocked up above the subgrade before the ballast is distributed. The setting of ballast stakes has already been described. The ballast should not be distributed until the banks are properly completed and the roadbed is finished to the standard cross section, so that the material will not be mixed with the earth and clay of the roadbed. In reballasting, if the original material

is very old and dirty it should be removed entirely, as it prevents proper drainage. Old broken stone ballast may be shoveled out and then handled and put back with forks, thus freeing it from dirt. On roads having a good supply of gravel available, it will be found economical to have gravel trains at work to keep the track well ballasted, as this will tend to reduce the maintenance work in wet weather, or in winter when the frost is in the ground. On the other hand, it must be recognized that ballast is usually somewhat expensive, and should not be used for filling in sags or wasted down the slopes of banks. Slag, however, being usually very cheap, may be used for both filling and ballast. The minimum depth of ballast under the ties should be 8 ins., or 12 ins. for first-class track. The cost of ballasting with 6 ins. of gravel below the ties is estimated at $580 per mile of single track, of which $320 is for delivering the gravel and $260 for putting it in the track. This is based on 30 miles average haul; $15.11 per day for engine, train and crew, and 11 cts. per hour for labor. The cost of train includes engineman, fireman, flagman and conductor, the latter acting as foreman of the gang.

The ballast may be loaded onto the cars by a steam shovel, or by a conveyor fed by a shoveling gang. The men's scoops may be suspended from an overhead frame so they do not have to lift each load in taking it from the bank to the conveyor boot. Ballast is sometimes carried in ordinary gondola cars, but more generally on flat cars with low hinged sides, or sides of loose boards supported by short stakes in the stake pockets, while iron aprons between the cars serve to keep the ballast from falling on the rails. A car 33 ft. long and 9 ft. wide can be loaded with 10 to 12 cu. yds. of ballast, or 14 to 15 cu. yds. if 12 in. side boards are used. Hand shoveling is expensive work, unless for small pieces of work or where small quantities have to be thrown off various points, and plowing or automatic dumping is more economical and more commonly employed. For plowing, the cars must be without ends, and flat cars are commonly used, as above noted. The Wisconsin Central Ry., however, has 40-ft. cars of 32 cu. yds. or 50 tons capacity, with sides 3 ft. high, hinged to a top rail, and locked by cams on a shaft running along the sill. When the sides are unlocked by throwing a lever at the end of the car, and the plow is drawn forward, the pressure opens the doors and allows the contents to escape.

Where the ballast is to be plowed off the train, the rear car carries a heavily weighted wedge-shaped plow, extending the full width of the car, and shaped to throw the material off on one or both sides. It is usually guided by the side stakes of the cars. To the nose of the plow is attached a steel cable extending over the cars to the locomotive, and led through pulley blocks on chains attached to the sides of the cars if the unloading is to be done on a curve. The train is stopped at the place where the ballast is to be unloaded; the car brakes are set, and the locomotive is then uncoupled, the cable attached to it, and the engine then moves slowly ahead, hauling the plow along the cars and plowing the material to one or both sides, according to whether a side or a center plow is used. The Barnhart plow has a front and rear guide to keep it steadily in the center of the car, the cable being attached by a hinged joint to the front guide. With loose gravel, the engine can be run at about 4 to 6 miles per hour. When the plow has been drawn the length of the train, the cable is unhooked and

thrown to the side of the track for the use of the next train. In filling and ballasting on the four-track work of the New York, New Haven & Hartford Ry., when the cable had been hauled the length of the train it was thrown to the side of the track and its end was hitched to a stand or derrick resembling a mail crane. The next train, running slowly by, picked up the cable, placing the end on the first car, while the stand held it in position over the cars until laid the full length of the train. The cable was thus handled by one man, while in ordinary practice it takes several men a considerble time to place the heavy steel cable on the ballast cars.

When distributing ballast in this way, the entire train load must be plowed off at one place. A very convenient arrangement, however, by which the distribution can be regulated, is by the use of the Lidgerwood "rapid unloader," which consists simply of a winding engine mounted on a car between the engine and the first ballast car, steam being supplied from the locomotive or from a boiler on the car. With a train made up in this way all the material may be dumped in one place, or any desired quantity can be unloaded and distributed by the locomotive moving the train along while the plow is being hauled along the train.

Various forms of dump cars are used in ballasting and filling, and it is especially desirable that the quantity dumped should be capable of being regulated. The Rodger cars are 34 or 40 ft. long, of 18 to 30 cu. yds. (or 25 to 40 tons) capacity. The sides slope inward and form a long narrow hopper parallel with the track, with doors arranged to deliver the ballast in the middle of the track and not pour it over the rails. The hopper doors are opened to any desired width by a man walking along the cars, the quantity delivered per yard of track being governed by the speed of the train and the width of hopper openings. At the rear of the train is the plow or spreader car, which is a flat car fitted with a double mold board steel plow, with flanges fitted to the edges. This plow can be raised or lowered by a screw and rides on the rails when in use. The ballast delivered in a ridge between the rails is plowed down between the ties and out over the rails (the rails being cleared by the flangers) so that it lies between and outside the rails ready for tamping as soon as the track is raised by the jacks. The train can be run at the rate of 3 to 5 miles per hour while delivering the ballast. Pratt cars, used on the New York, New Haven & Hartford Ry., are of 25 cu. yds. capacity, or 30 tons carrying capacity. They are 28 ft. long inside, and weigh about 25,000 lbs. empty. The sides are made in two parts, divided horizontally. When the train stops, the upper half of the side of the car is swung down, and half the load dumped. The train then moves on a train length and the lower half of the side is swung up, dumping the rest of the load. The Goodwin cars are built entirely of steel. Only the top part of the side is fixed (18 ins. deep), doors inclined inward forming the lower part, and resting on a narrow movable bottom piece at the center of the car. Inclined aprons extend over the wheels. The car can be dumped by hand or by air, while the train is moving at 5 to 8 miles an hour. The material is deposited on either or both sides or between the rails. The cars have a capacity of 28 to 30 cu. yds., or 40 to 50 tons. The Page car has three or six dumping boxes mounted on the car frame, which can be dumped independently or

simultaneously by means of levers. Small four-wheel dump cars of 4 or 5 cu. yds. capacity are sometimes used on contract work. Many roads haul ballast, cinders, etc., in cars with sloping sides and removable or hinged doors, the material sliding out as soon as the sides are removed or released. As ballast trains are expensive and cause delay to regular trains, the plan is sometimes adopted of delivering small quantities for repair work by means of dump cars hauled in way freight trains, the brakemen dumping them at certain points, according to instructions. For distributing ballast in this way, the Michigan Central Ry. uses special cars of 25 to 30 cu. yds. capacity. The bottom slopes steeply to each side, and transverse bulkheads form six pockets or compartments. Each compartment has a swinging door at the side of the car, and a swinging board half way up the slope, subdividing the pocket. Thus a large or small amount of ballast can be dumped at any point, as desired. A few of these are put together in a train which is stopped at the required spot (marked by stakes) and the trainmen release the outer doors, the amount of ballast being sufficient for a raise of 6 to 8 ins. in the length of the car. The train then moves on, and the inner doors are released, depositing the same amount of material adjacent to the first.

When the ballast is distributed, the track is raised by jacks (both sides at once) for a distance of about 100 ft. and lined by bars. The ballast is then thrown into place between the rails and tamped under the ties. Coarse stone or slag is handled by forks instead of shovels. Two lifts are usually made, and the inclined parts approaching the raised portion must be made solid enough to prevent injury to the rails and joints by passing trains. The shoveling back of the ballast from the sides of the track and throwing it between the rails may be avoided by the use of dump cars depositing the ballast between the rails, as with the Rodger cars above mentioned. Where ballast is deposited at the side of the track for additional tracks, there may be at the rear of the train a spreader car, with an adjustable wing which projects so as to level and spread the material for a width of about 12 to 15 ft. from the ballast train track, on one or both sides as required. These spreader cars, which have been used for leveling ballast and earth work on several roads, are usually heavy flat cars with a heavy trussed gallows frame or side posts, from which run stays to the outer end of the spreader or wing which is about 20 ft. long, built of plank and faced with iron. Adjustable braces are fitted between the wing and the sills of the car, and it can be raised and lowered or adjusted as to position by a chain on a winding drum or by air cylinders. With movable pieces or mold boards attached to the bottom of the wing, the ballast can be trimmed to the required cross section, and ditches can also be trimmed and cleaned. (See also "Ditching"). When not in use the wings are folded against the side of the car, which can then be hauled in any freight train.

In building the additional tracks for the four-tracking of the New York, New Haven & Hartford Ry., between New York and New Haven, a temporary track of old material was first laid on the subgrade, and the ballast then hauled in and the temporary track raised by jacks to the proper grade. After this the old track was replaced by the material for the permanent track, which was thoroughly tamped, surfaced and lined. The

ballast was of broken stone, carried on low, drop sideboard cars, each holding 10 cu. yds., and the unloading was done by hand. From this first new track the ballast for the two adjoining tracks was then unloaded, and was leveled off to the bottom of the ties by means of a spreader. This consisted of a heavily loaded flat car fitted with wings 20 ft. long, the wings having plate iron scrapers, adjusted by means of two ratchet jacks. On the bed thus prepared the new tracks were laid, and were ready for slow running trains as soon as the spikes were driven, there being no danger of bending the rails. A similar plan is often employed in building additional tracks, and it will readily be seen how the ballast may be distributed and leveled for any number of parallel tracks after the first track has been laid.

When gravel ballast is to be put in on a track ballasted with earth, the earth between the ties should be dug out and placed at the side of the roadbed. A train load of gravel is then dumped, giving about 15 cu. yds. per car length, and this is then packed down to make room for another load, filling it in level with the tops of the ties. The track is then raised by jacks, and the gravel shoveled under the ties, after which another load of ballast is deposited. The track is then again raised, the ties are spaced properly, the final tamping done, the track lined and surfaced, and the ballast finally dressed to the required cross section.

CHAPTER 18.—DRAINAGE AND DITCHING.

The drainage of the land traversed by the railway is an important matter, but comes more properly under the head of construction or engineering work than of maintenance or track work. It is not intended to consider this matter here, but rather to consider the drainage of the railway as constructed. There are, however, some general points which it may be well to briefly mention. The necessity of providing ample waterway at all bridges and culverts is insisted upon in nearly every book on railway work, but it is not always as closely observed in practice as it should be. In the maintenance work, therefore, the engineer, roadmaster and section foreman should have in mind what culverts or waterways are occasionally found to be of insufficient capacity. Until increased capacity can be obtained they must take care that the opening is free from drift and obstructions and protected against wash, that no fencing is placed across it and that the sides of the stream or the slopes of the embankment, etc., are protected from wash. This protection may be in the shape of rip-rap, brush, rough cribbing of trees and logs, or trees laid on the slope with the trunks pointing up stream, and the branches weighted down in the water. No fences or wires should be allowed across drainage openings, as these check and collect drift in times of flood.

It is now generally recognized that as every opening on the railway is to a certain extent a source of danger, these openings should be reduced to a minimum, and therefore the common open culverts are on many roads being rapidly replaced by culverts of iron or vitrified clay pipe (one

or more lines of pipe according to the waterway required), stone box drains, or masonry arches, with a solid bank filled in over them. Such culverts, of proper capacity, and with ends properly protected from scour, are, of course, much less liable to washouts or undermining than pile culverts. Rectangular or box culverts of masonry should have a waterway not less than 2½ × 3 ft. The abutment walls should be at least 2 ft. thick (or two-thirds the height), resting on a paving of 10-in. stone, set on edge, the ends of this paving being protected by curbing and broken stone aprons. The covering should be of stone 12 in. thick, with 10 ins. of bearing on each wall. Steel plate culverts are used to a small extent.

The method of draining the water from the track and from the land on each side will depend upon the character of the soil and the amount of water to be dealt with. In some exceptionally bad cases, special treatment is necessary to prevent slides, particularly where quicksand, gumbo, or clay overlying rock are encountered. In Europe, heavy permanent works of masonry are sometimes undertaken for dealing with slides, or for the drainage of wet or unstable material traversed by a railway. Valuable articles on this class of work will be found in "Engineering News," New York, Sept. 22, 29; Oct. 6, 13, 1877; in the "Journal of the Association of Engineering Societies," 1894; and in the "Annales des Ponts et Chaussees," October, 1893.

In all cuts there should be a good ditch on each side of the roadbed, and the distance of the ditch from the rails should vary with the material of the cut, for in rock or hard material the water may be safely carried closer to the ballast than in wet clay or earth, when the water will seep into and tend to saturate the roadbed. From this it follows that cuts in soft material should be wider at subgrade than those in hard material, although in practice the cuts are often made too narrow to allow of proper ditches, and expense is incurred in subsequent widening or in constant maintenance and in cleaning ditches. The slopes, also, are often left too steep, thus preventing the construction of proper ditches, and increasing the liability of slides in wet material, or causing a constant falling of material into the ditches. Some of the wet gumbo cuts on the Canadian Pacific Ry. have had to be cleaned out and deepened with a steam shovel and then two rows of piles, 8 ft. apart, driven on each side of the track. Sills laid under the roadbed kept the inner rows from moving, and inclined braces were put in between the inner and outer rows. The mud was dug out and coarse gravel filled in around and behind the piling through which gravel the water drained to the track ditches. On the Savannah, Florida & Western Ry., a clay cut, about 20 ft. deep and 300 ft. long, at a point that was formerly the head of a small natural drain, gave a great deal of trouble during wet weather by the slope on one side sloughing off and falling in, causing the track to rise suddenly, sometimes as much as 3 ft. in one night. Tons of this earth were removed as it fell in, until the earth from that side of the cut had been removed some 70 ft. from and to a level with the track, still the difficulty was not overcome. Open ditches failed to reduce the saturation of the semi-liquid mass. A tile drain 6 ins. diameter was carefully laid parallel with the track, 4 ft. from the ties and 3½ ft. below the level of the track, on the side where the sloughing occurred. An open ditch was dug on the opposite side of the track. In the first wet

spell after this the track again began to rise and had to be cut down, and the open ditch reopened repeatedly. The tile drain was broken up by the movement of the earth, and parts of it found to have passed entirely under the track into the ditch on the opposite side. Soundings indicated that the soft mass extended about 30 ft. below the track, and was apparently slipping over a strata of hard clay with an inclination toward the track. A row of round sheet piling was driven about 8 ft. from the track and 20 ft. deep. It was intended to brace this piling by means of struts under the track and against the opposite wall of the cut, which stood immovable; but a season of heavy rain coming on prevented the execution of this part of the work. It was expected that the earth would force the piles toward the track, and that the old difficulty would again reappear. Such was not the case, however, for, notwithstanding months of heavy rains, the piling and track remained unmoved.

Round or sheet piling is also sometimes necessary in the slopes or at the toes of cuts. In soft cuts deeply gullied by rain, cribs of old ties are sometimes used, but are very unsightly and generally of only temporary value. If such cribbing is used, the pile of ties should be higher at the track end, the ties sloping back to the bank, so as to afford greater resistance to displacement of the cribbing, while the edge forms a convenient platform from which to shovel the sliding clay into the cars until the angle of repose has been reached. It has also been found in cuts through clay with an overlying stratum of earth, that if the material is excavated to a vertical face at about the middle of where the ordinary slope would be, when the face sloughs off the earth will cover the clay and protect it from the weather. Where slides occur or are liable to occur, and it is difficult to keep the ditches clean, some additional means of drainage should be provided. Wooden box drains, pole drains, or trenches filled with saplings may be used in wet cuts. If a slide occurs in winter or in bad weather, ditching it out will often keep it sliding or make it worse, and in such cases, as long as the material does not encroach on the track, it is often best to leave it and cut cross drains through the ballast to carry the water to the ditch on the other side of the track. If the proper width for slopes and ordinary ditches cannot be obtained, as in cuts through valuable property, masonry retaining walls may be built near the track, and the slopes commenced from the tops of these walls.

One of the great troubles from heavy rainfalls, is the gullying out of the slopes and the breaking down of the corners of cuts and banks, for which reason it is a good plan to round off the top and bottom corners, as in the section shown in Fig. 203. Mr. D. J. Whittemore, Chief Engineer of the Chicago, Milwaukee & St. Paul Ry., has advocated this course, together with the paving of ditches and the sodding of slopes. The washing of slopes, especially in sidehill cuts, may be checked by cutting a berme or surface ditch at some little distance from the top, so as to intercept the surface drainage. The ditch should be at least 3 ft. from the cut, with the earth thrown out on the side next the cut. It may be about 18 to 24 ins. deep, 12 in. wide at the bottom, the size varying with the amount of water to be dealt with. The ends should be curved out, or led into the berme ditch of the adjacent bank, so that the water will not wash the face of the bank. If the earth is very soft or porous the ditch may be lined with plank or even

concrete. Another method is to have blind drains cut diagonally along the slope and filled with bundles of brush or saplings, broken stone, or semicircular tile. In still other cases, trenches about 2 ft. wide and 2 ft. to 3 ft. deep are cut straight up the slope and filled with broken stone. The distance between these trenches depends upon the amount of water and the character of the material. Where springs break through the slope, drain pipes may be inserted, and a gutter or an apron of stone rip-rapping laid from the outlet down to the track ditch. In such cases, subdrainage may be required.

A sodded slope will prevent washing, and largely prevent sliding, except with very wet material and a continuous heavy rainfall. In England great care is taken with the sodding and grassing of slopes of banks and cuts. On the Cape Cod Division of the New York, New Haven & Hartford Ry., the slopes of sandy cuts and banks are protected somewhat from rain and wind by encouraging beach grass to grow on them, but as this will not grow so well on the slopes of cuts, old ties are sometimes laid on the latter. The roadbed of the Southern Pacific Ry. on the south side of the San Gregonio

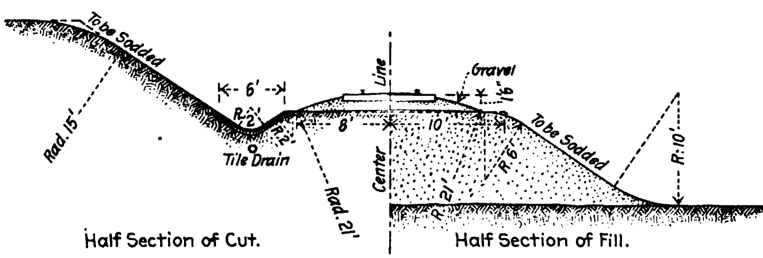


Fig. 203.—Cutting and Embankment with Rounded Corners.

Pass (in southeastern California) was originally composed of sand, and sometimes suffered during high winds. This was checked by embedding dry brush in the embankment, with tops and branches outward. Where the Siberian Railway crosses sandy plains, the roadbed is protected by rows of low scrub bushes, which serve both to prevent the sand from being blown away and to consolidate the soil by their roots.

Banks may be drained by berme ditches not less than 3 ft. from the toe of the slope, and material should never be taken from the intermediate berme or level for filling the bank or raising sags. The bottom of the ditch should slope slightly away from the bank. If there are springs underlying the bank, the tile drains may be laid from the springs to the side ditches, or the earth may be dug out, broken stone and rock filled in, and rock-filled trenches made from the hole to the ditches. Special care should be taken with the drainage on sidehill work to keep the bank itself and the ground upon which it rests well drained. In some cases benching and extra side filling or dwarf retaining walls are required to keep such a track in line. Trackmen should never be allowed to use the material from the top of the bank for ballast. The laying and cultivation of heavy soil will do much to consolidate and hold the bank.

Swampy ground requires special treatment of the roadbed, and the Canadian Pacific Ry. has built some sawdust banks across swamps where gravel would break through the surface crust. The slopes are covered with earth to protect the material from fire. The Minneapolis, St. Paul & Sault Ste. Marie Ry. crosses a number of swamps in Wisconsin, many of which show soundings of 15 to 30 ft. Upon these is made a roadbed about 2½ ft. high from ditches cut at a distance of 15 to 30 ft. from the foot of the slopes. The material is mostly peat, which, when dried out, makes a very light bank. The track was laid on small poles (3 to 4 ins. diameter), three under each end of the ties, and only enough ballast was used to bring the track to a good surface. These swamps gave some trouble from the track crawling under the heavy consolidation engines (120,000 lbs. on the driving wheels). In some places ties 10 and 12 ft. long were used, and angle bars were bolted to the middle of the rail and spiked to two ties. A 12-in. foundation of logs, about 6 ins. diameter, is sometimes built across swamps, being covered with bushes and a little ballast. Ditches are usually dispensed with in such construction.

Subdrainage and Tile Drains.

Subdrainage is frequently necessary where the roadbed is in damp or wet ground, and where trouble is caused by heaving. Tiles and broken stone are used for this purpose, the tile being the better. The tile drains are usually laid under the ditches on one or both sides of the track, and 2½ to 3 ft. from the bottom of ditch to bottom of tile is generally sufficient, but in any case the tile should be below the frost line to protect the tile from heaving or breakage. The ends of the drains discharge into culverts or waterways. Good track cannot be maintained in wet and soft places without subdrainage, and there are many spots in cuts and under banks (especially in sidehill work) where water seeps through badly, and where nothing but subdrainage will afford substantial relief. In wet cuts the tile may be laid in diagonal lines at a depth of about 3 ft., and 6 ft. to 20 ft. apart, or to form lateral drains leading to the side drains, while the slopes may be drained by tile laid in trenches and connected with the side drains.

The best and cheapest material is the common red clay drain tile, without collars, though glazed tiles with open joints are used in some cases. The smooth surface of the tile gives a rapid flow for the water and consequent reduction of saturation of the roadbed. It should be not less than 5 ins. diameter, and of ample size to carry off all the water freely, as there is little difference in the cost of laying 5-in. or 10-in. tile. Great care should be taken to lay it properly, getting tight joints and uniform grade with all the fall the outlet will allow (the grade to be not less than 3 ins. to 100 ft. in any case). It should be covered with marsh grass, if possible; although hay or straw are better than nothing, while open joints should be covered with strips of sod or turf. The trench is then filled with cinders, gravel or other porous material, if any can be had. Otherwise stiff joint clay may be used, but not sand or loam, as they will work into the pipe. The trench, however, may be filled with such material. In laying in quicksand or mud it may be necessary to use a plank bottom or trough covering as fast as laid, to prevent displacement. When putting in tile on only one side of

track, it should be laid on the upper or higher side. Where a spring underlies the roadbed in a cut, tile cross-drains may be laid at intervals, sloping slightly towards the sides and connected at each end with the tile drains under the ditches. The outlets of all drains should be looked after and kept free, especially in winter, as springs may keep water running in cold weather. Some loose stone should be laid up around the ends to keep out small animals, or wire netting answers admirable for this. Both ends of the drain should be kept open and free to allow circulation of air through the drain. The cost of laying tile will vary from 25 cts. to 60 cts. per rod, according to material, or even more in quicksand cuts. In general the drains, if of any extent, are laid by men experienced in this particular work, and not by the ordinary section gangs, as the former can usually do the work quicker and cheaper. In laying the drains, the tiles or pipes are kept in line during tamping by stringing them upon a pole or rod about the diameter of the pipe, this being left in place until a length of backfilling and tamping is done, when it is pulled ahead for another set of pipe, its heel remaining in the pipe already laid as a guide.

Ditches.

The proper construction of roadbed ditches has already been referred to, and on all roads in districts where much rain falls, one of the important items of track work is that of keeping the ditches clear and properly graded, for well-drained earth may make a better roadbed than badly-drained gravel. Earth from the slopes and ballast from the roadbed fall into the ditches and gradually form obstructions which choke the waterway, while in soft material the ditches will gradually close up. In the spring, therefore, as soon as the frost is out of the ground, every section foreman must have his ditches properly cleaned and improved; and in the autumn he must again overhaul them, clearing out leaves and rubbish, and putting them in condition for winter. In doing this work, attention should be paid to getting even grades, proper dimensions for an ample waterway, and a uniform direction, cutting away stumps, boulders or rock edges which interfere with the course of the ditch, as twists and bends around small obstructions are liable to catch floating objects and to cause a choking of the ditch. Attention must also be paid to getting a good discharge from the ditch at the end of the cut, so that the water will not wash the adjacent bank. The ditch should be commenced at the lower end of its grade, so that the work will drain itself as it progresses. Sections of ditches are shown in the chapter on Roadbed Cross Sections, Part I. On curves it may sometimes be necessary to carry the water along the inside of the curve to prevent washing of the roadbed or ballast, and for this purpose the outside ditch is dammed at intervals and an open box drain of wood laid across the roadbed to carry the water to the inside ditch. When ditching in yards, the foreman should arrange with the yardmaster and do the work at a time when the sidetrack next the ditch can be kept clear of cars.

Ditching is usually done by hand, the earth being shoveled into a push car, which is then run to the end of the cut and dumped over the bank, a flagman being sent out to protect the car. The earth should never be

thrown upon the slope of the cut, or on the top of a shallow cut, as it will only wash or fall in again. If the earth can be loaded, hauled and dumped by a car, as above described, without interfering with trains, this is the best way to work. In many cases, however, wheelbarrows are more convenient, a wheeling plank being laid on the inside of the near rail, care being taken that the planks are not so thick or warped as to interfere with the flanges of car wheels. Wheelbarrows having grooved wheels to run on the rail head are sometimes used, and are claimed to be specially useful where the traffic is heavy and two flagmen would have to be sent out if a car was used. In wheelbarrow work, the foreman should put one of his best men in front and a second best man at the rear of the wheeling gang, so as to get out to the dump and back again as quickly as possible. If the work is extensive, a work train and extra gang may be assigned to it, the earth being loaded on flat cars and hauled to any convenient place for deposit. Whether it is best to employ trains, push cars or wheelbarrows, will depend upon local conditions, the length of cut, number of trains during working hours, extent of work to be done, number of men in the gang, etc.

Ditching Machines.

On railways running through low-lying, damp and swampy districts, and having the grade line but little above the normal surface of the country, the question of drainage is a very important one in the maintenance-of-way work, and a considerable amount of money and labor must be expended in making and maintaining ditches in order to keep the roadbed and bank in proper condition. This is especially the case where the ballast is poor, and where the natural soil is used for ballast. A combination of the above conditions exists on a large mileage of railways in the Southwest, and there is consequently a good field for the application of ditching machines in order to expedite the work and reduce the cost for labor. A handy and labor-saving device is a ditching car, which consists of a heavy framing mounted on a flat car and supporting two derricks at the side (or two derricks on each side for single track work). The derrick chains support the front and back bails of a ditching scoop or scraper of about 1 to 3½ cu. yds. capacity, while a chain from a horizontal bail in front of the scoop is fastened to the front of the car. This chain does the pulling, the others regulate the depth of cut, and the derrick regulates the distance from roadbed to ditch. There is a man at the winch of each derrick, and the crew consists of 8 men in all. If operated by steam or compressed air a smaller gang will suffice. The machine will work in dry cuts when they have been plowed, but it works best in wet weather, when the material is soft. The car should be strong and well braced, and have the spring hangers duplicated or reinforced, as it is subjected to severe strains. There should be no slack between the engine and car, so as to prevent jerking. Cars of this kind are used on a number of railways, and can be rigged up on any division, and fitted with a ditching plow, a ditching scraper, or a mold board for dressing ballast slopes, as noted in Chapter 17. The machinery may be housed in, the cabin (or a separate car) being provided with a blacksmith's forge, tools, etc., for making repairs required in service.

On the Intercolonial Ry. the wings of a snow plow have been fitted with

vertically adjustable steel cutters, 13 ins. deep, 9 ft. long and ⅞-in. thick. The first cut is made with the wings half open, cutting the ballast slope. The second cut is made with the wings spread to their full extent, forming the berme at the level of the subgrade and plowing the stuff down the bank. Formerly, two or three furrows were plowed with a farm plow and a pair of horses, the sods being thrown down the bank by trackmen with forks. The above machine is hauled by a locomotive, and can clean 20 to 25 miles of track in a day, making a cut on each side 3 ft. to 9½ ft. from the rail and to a depth of 2 ft. below the top of the rail. The crew consists of two men to extend or close the wings, and two men to raise and lower the cutters at crossings, switches, etc. Such a machine is specially valuable on single track roads with limited section forces, and it can be made out of a wing snow plow, or by attaching wings and cutters to a box or flat car.

A very completely equipped car for heavy work of this kind has been designed by Mr. W. B. Doddridge, General Manager of the Missouri Pacific

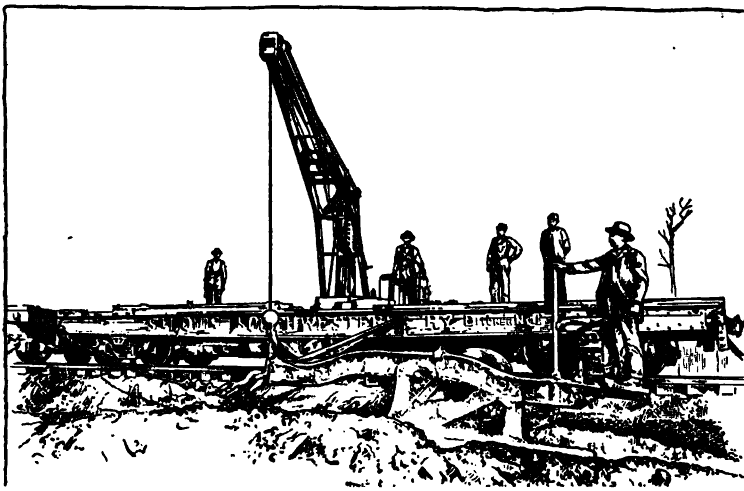


Fig. 204.—The Doddridge Ditching Machine.

Ry. It is 46 ft. long, having plate girder side-sills connected by angle iron transverse bracing. The end sills are heavy steel castings, and have extended curved ends to serve as attachments for the draft chains which pull the outer end of the scraper and the beam of the ditching scoop. At the middle of the car is a steel derrick post, 9 ft. high, seated in a frame below the floor and carrying a crane arm or jib having a reach of 14 ft. The crane can be turned through a complete circle. All operations are effected by compressed air stored in three cylindrical reservoirs, 2x10 ft., at a pressure of 80 lbs. per sq. in., and supplied by the air-brake pump of the locomotive. Underneath the cars are also placed the operating cylinders: 12 ins. x 14 ft. 7 ins. for the derrick hoist; 12 ins. x 9 ft. 5 ins. for swinging the derrick, the piston rod having a rack attachment for swinging the mast through a complete circle; and four cylinders, 8 ins. x 5 ft. 4½ ins. for

the side guides. The pistons are cushioned by air, and the cylinders take air from either end. The various pipes are brought together to a switchboard, mounted on the car, and from which all movements are controlled by means of cocks. The main equipment of the car includes the following: (1) A solid cast steel plow, weighing 2,500 lbs., which cuts a furrow 20 ins. deep and 36 ins. wide; (2) A triangular shaped scraper for cutting material for the embankment; (3) A mold board for dressing the roadbed to the standard section; (4) A ditching scoop of 3 cu. yds. capacity. Fig. 204 shows the machine at work plowing for the ditch.

In operation, the plow is first used to cut one or two furrows as may be necessary, to lower the ditch to the proper depth and furnish sufficient dirt to fill out the embankment to the standard section. The necessary beams, guides, etc., are so arranged that the plow is entirely under the control of the man handling the air; it can be set at any distance from the track that is desired, raised or lowered, or swung in or out to avoid obstructions too large to plow up. The nose of the plow is braced by a heavy bar attached to the side sill. The scraper is then used to bring the dirt from the ditch up toward the track. If the ditch is in a small cut, however, with banks not exceeding 5 or 6 ft. high, and the dirt is not required on the bank, the scraper can be reversed so as to remove the dirt from the ditch, throw it outside and form a bank of even and regular surface. The mold board or shoulder former is then used to dress up and finish the embankment. This board extends from the ends of the ties at an angle of 30° with the car body, for a distance of 14 ft. As it is braced and held rigid with the car, the embankment is shaved perfectly smooth and exactly to the form of the template bolted to the lower edge of the mold board. Where the scraper has brought up too much dirt, the mold board removes it, carrying a sufficient quantity before it to fill up the low places where not enough dirt has been left. The board can be readily adjusted as required, and can be raised easily to allow it to pass cattle guards, bridges, and road crossings. The track is then ready for ballasting.

The ditching scoop or excavator is an important part of the equipment, when ditching in deep cuts or preparing to lower track. It is attached to the car in the same way as the other tools, and is worked somewhat in the manner of a drag scraper or the dipper of a steam shovel. The dirt is scooped up and the car run out on the embankment, where it is dumped. The whole operation is handled by air, the derrick raising and lowering the scoop and tipping it to dump the load. With this tool, cuts can be excavated to any depth desired, from the ends of the ties out to a distance of 14 ft. The scraper and the scoop are attached by chains to a heavy steel beam, pivoted to the extension of the frame below the sills, and held in position by chains from the side and a rod from the end sill. The mold board is hauled directly by a chain attached to the end sill.

It has been found most convenient to work an entire day on one side of the track. When not delayed too much by passing trains there is no trouble in ditching and dressing up the embankments on one side of the track for a distance of 1½ to 2 miles per day, leaving a neat, well-drained and well-trimmed roadbed. The force required to operate the outfit consists of the conductor of the work train (who acts as the foreman of the work), two brakemen, one man to handle the air, and two laborers to make and change

the various chain hitches. The entire cost of such labor is $18.30 per day. The locomotive propelling the machine moves at a rate of about four miles per hour, hence it is stated that the amount of work done in a day, at a total cost of about $30, would cost $500 to $1,000 if done by laborers. Besides this the embankment is left perfectly true to the standard section and in better shape than would be possible if the work was done by hand.

CHAPTER 19.—TRACK WORK FOR MAINTENANCE.

The maintenance work on track includes the various kinds and details of work required to keep the track in safe and proper condition for traffic. It varies, of course, with the climatic conditions, and also varies with the character of the track and the amount of traffic, being specially hard under conditions of a light track carrying a heavy traffic. If the road has been carefully located and built, with easy curves, well arranged grades, and a good track, then the maintenance-of-way department has an excellent chance to maintain a practically perfect track at small expense. If, on the other hand, the road has been laid out and built hurriedly and carelessly, with a main view to cheapness, and if it has narrow cuts and banks, curves used recklessly and badly put in, and long steep grades used unnecessarily, then there will be trouble with the trains and continual trouble to keep the track in reasonably fair condition. Many railways now recognize the principles of economics, and are building, rebuilding and maintaining their lines accordingly. Eventually, all important lines will use rails of ample weight and strength for the traffic, will take means to prolong the life of ties, and so reduce the frequency of renewals, and will purchase material for merit rather than price. With such a system a great reduction may be expected in the labor and expense of maintenance. It is not sufficiently recognized by executive officers that the increased cost of maintenance with old rails and ties, worn-out fastenings and poor ballast often exceeds the interest on the investment for new material. Heavier and stiffer rails, which distribute the weight of trains over a greater length of track and give but slight deflection, materially reduce the work of maintenance, as noted under "Rails" and "Track Inspection." The cost of the work varies from $600 to $1,000 per mile, as already explained in Chapter 16, and the following table shows the distribution of labor cost for maintenance work on the Delaware Division of the Erie Ry. in 1894:

	Per mile.	Per c't.
Surfacing	$151.46	37.8
Renewing ties	45.68	11.4
Other track repairs	90.16	22.5
Snow and ice	14.43	3.6
Wrecks, slides, etc.	48.48	12.1
Helping other departm'ts	$45.68	11.4
Construction & new work	4.81	1.2
Total	$400.70	100.0

From 60 to 75% of the damage and wear to track is caused by the engines or engine mileage, and the balance by the trains, with their far greater number of wheels. This is due to the greater wheel loads, the closer concentration of these loads, and the destructive effects resulting from bad counterbalancing, slipping of driving wheels, use of sand, etc., to say noth-

ing of the wear of frogs and switches by badly worn driving wheel tires. The car is merely a passive rolling weight, and while flat spots in car wheels or the general use of very heavy car loads may aggravate the destructive effect of the wheels, it is not probable that the proportion of damage due to the train would approximate that due to the engine wheels. Freight trains are usually more severe upon the track than are passenger trains, as the engines of the former are more liable to be pulling hard, while the cars ride harder owing to the spring rigging being more rigid than on passenger cars. Day cars weigh about 26 to 40 tons (or 6,500 lbs. per wheel); sleeping cars, 45 to 55 tons (7,500 to 9,333 lbs. per wheel). These weights are distributed over a wheelbase of 40 to 65 ft. Freight cars have a wheelbase of 18 to 25 ft., and weigh from 12 to 20 tons empty or 30 to 75 tons with full load. This givés wheel loads of 3,000 to 18,500 lbs. Freight locomotives have axle loads of 15 to 22 tons, and impose loads of 65 to 100 tons on a driving wheelbase of 14 to 17 ft. The total load on the length of track covered by this wheelbase must be taken into consideration, as well as the concentrated load per axle or per wheel.

The work should be done systematically, and not at scattered points along the sections. Standards should be adopted and followed as closely as practicable. The amount of time and labor which may properly be expended on the appearance of the track depends largely upon the financial conditions. Hand dressed ballast, turfed slopes, etc., can only be expected on comparatively wealthy roads, but neatness of work should be seen on every road, as neatness involves no expense, but is rather conducive to economy. Mere ornamental work, such as nicely dressed but poorly tamped ballast, is sufficient evidence that the man in charge of it is not fit for his position. The maintenance of way is an endless work, the basis of which is surfacing, and its monotony is varied occasionally by more or less extensive extra work in the way of relaying track, reballasting, or building additional tracks. It may seem trite and unnecessary to remark upon the necessity of good work, but how often are seen (even on leading roads) rail joints with bolts missing, ties misplaced, old shims left in place, etc., and work done to look well. It is not always possible for the roadmaster or engineer to get what he considers to be the best materials, and he must then do the best with what he has. Thus many a man considers tieplates to be more effective than rail braces in maintaining gage on curves, but if his road will not supply the plates he must use the braces to the best advantage. He may also have bad sags in the grade line, causing trouble with freight train couplers, but if he is unable to get the material necessary for filling in he must do his best to ease off his track at the ends of the sag to give a more even approach. In case of any important work being undertaken the traffic department should be notified.

In the general work on the section, the roadbed slopes and ditches must be maintained according to the standard plans, and if the original construction does not conform to these standards, then all subsequent work should be done with a view to attaining them. In some cases the standard dimensions (as for ditches, etc.,) may not be sufficient under local conditions, and in such cases they should be exceeded so as to give the required capacity. All material taken out in widening cuts or ditching should be hauled away and used for widening banks, being shoveled clear

of the ties and below the level of the bottom of the ballast so as not to interfere with the drainage. The ballast must be kept free from weeds and in proper slope, being promptly restored to shape when broken down by stock or trespassers. Center and grade stakes should be tested and reset every three or four years, and on sharp curves and transition curves the center stakes should be tested once a year. The track must be maintained in line, gage and surface, for any deficiency in one affects the others. Besides the maintenance in detail, the condition of the division as a whole must be seen to. The profile and alinement should occasionally be tested, especially where maximum grades limit the hauling capacity, as any increase in the grades or curves, or improper compensation of grade, may seriously affect the train service or the economy of operation.

One of the greatest causes of bad track, hard riding track, and damage to rails, is the low rail joint. When a joint has once become low it rapidly gets worse unless promptly attended to. If the ballast under such a joint is dirty or bad it should be cleared away and good ballast put in and well tamped. In many cases rails are badly damaged and bent by hauling over them "dead" locomotives (not using steam) with the side rods taken off, the counterbalances then having a very destructive effect on the track. Rails, frogs and switches are also subject to injury from engines with badly worn tires. All such cases of damage should be promptly reported, and the transportation department should adopt strict rules as to the speed at which "dead" engines may be hauled. When a broken rail is found it should be at once spiked, and, if possible, a pair of splice bars placed at the break and bolted or spiked. Trains should be flagged until the broken rail has been securely spiked and spliced or a new rail put in. An investigation should be made and a report prepared in each case of rail fracture. Switches should be frequently examined, to see that the switch rails have the proper throw; the switch rods adjusted to give the proper position of the rails, connecting pins in place and secured, and slide plates greased and free from dirt, stones or other obstructions. Spring-rail frogs must also be looked after and kept free from obstructions. Particular attention must be paid to the telegraph lines. If found broken or on the ground, crossed or obstructed, they must be at once repaired in a temporary manner and due notice given. Should repairs be impracticable, notice must be sent at once to the nearest telegraph office. Where a track circuit is used in connection with the block system, etc., care must be taken that the bond wires at joints are not cut or broken. If any are accidentally broken, they must be at once repaired by the foremen, and a man sent to look to the signals affected.

In tunnels and on bridges the work of maintenance is of a somewhat special character. Refuges should always be provided at intervals in tunnels and on long trestles. If there is heavy traffic through the tunnel, the maintenance work is specially difficult, and the men cannot work to advantage, as they have to be continually getting off the track and seeing that their bars, tools, etc., are clear of the rails. Foremen should be particularly careful in such cases, and should display "slow" signals if they are doing any heavy work. Portable electric lights, oil lamps or torches, or Wells lights may be used, the latter being of special advantage. The work of renewing ties, rails, etc., under such conditions, is not only difficult and dan-

gerous, but expensive, and it will be economy to make a somewhat large expenditure upon an exceptionally heavy and substantial track, so as to reduce the maintenance work. When the track is found out of line or surface at bridges and trestles, the roadmaster should make an investigation and notify the officers of the bridge department. Temporary repairs should then be made, if necessary, and "slow" signals put up until the track has been inspected and rectified.

Hand cars and unloaded push cars must be lifted from one track to the other at switches, the switches being thrown only for loaded push cars, and then by the foreman, who is responsible for closing them. Hand cars must be run with caution, and slowly in foggy weather and through towns or near grade crossings. They should not be used in foggy weather unless the place where the men are to work is more than a mile distant. They must not run within 20 minutes of the time of a regular train, nor in the wrong direction on double track. It is best to start directly after a train (care being exercised as to trains following closely), and on single track to then run the car at full speed to such a point as a train in the opposite direction may be expected. If there are curves and cuts on the line, obstructing the view of the track, a man may be sent ahead as far as he can see the car and also see further along the line. If he signals that there is no train approaching, the car can be run up to him at full speed, but if he signals that a train is approaching there is ample time to take the car carefully off the track. If the car is left near a road crossing while the men are at work, the wheels should be locked, but it is best not to leave it in such a place. Rails should not be carried on the hand car except in cases of emergency.

Before disturbing the track for rail renewals, etc., in such a way as to make it unsafe for traffic, the foreman must put out a flag and torpedo at a distance of 90 rails or 18 to 24 telegraph poles, these signals being put in both directions on single track. Some roads require the flags to be set at 24 poles and the torpedoes at 32 poles distance. The Louisville & Nashville Ry. requires a red flag and torpedo at 18 poles (2,700 ft.), and a green flag at 24 poles (3,600 ft.), the man to work near the red flag. The green flag may be omitted for only temporary obstructions. If trains must stop, a red flag and one torpedo are placed; if they are only to slacken speed, a green flag and two torpedoes are used. A man should be put in charge of the "stop" signal, being provided with tools for doing track work in its vicinity, but sometimes this is only done when the flag cannot be seen from the place where the gang is working. The man should work at some little distance within the flag limit, so as to be ready to attract the attention of the engineman if he should fail to observe the signal. The same signals are used in case of any obstruction on the track, lamps replacing the flags at night. When one gang of trackmen, bridge men, etc., passes another, the foreman of the passing gang must ascertain what signals the working gang has put out. Except in case of emergency, no repair gang must work between another gang and the latter's flags. If it is necessary for a section gang to work between an extra gang and the flag of the latter, a flag should be placed in the middle of the track, 100 ft. beyond the section gang (between it and the other gang) to warn enginemen that there is a second gang at work. No work that will obstruct the track or interfere with the passage

of trains must be undertaken in foggy weather, as in times of exceptionally heavy traffic. The foreman must have his gang clear of the track, and the track in safe condition 10 minutes before the time at which a regular train is due, except when the train is late and the permission is given by telegraph or written order. He must be ready for extra trains at any time, and must look out for signals carried by the trains. The principal train signals are as follows:

Train Signals.

Two green flags by day are markers to indicate the rear of the train, and if these are not shown the indication is that some of the cars have broken away or the train has parted. At night, the markers are two red tail lamps on the rear car (showing a green light at front and side and a red light at the back); also a red light on the rear platform of a passenger train and on the cupola of a freight train caboose.

Two green flags by day (or lights by night) on the engine indicate that another section of the train is following on the same schedule time. The engine of the last section of any train carries no such markers. Two white flags by day (or lights by night) indicate an extra train.

A white light on the platform of a passenger car, roof of freight car or rear of tender, indicates that the train or engine is backing, the engine then carrying a green flag or red tail light on the bumper beam. Two green lights are carried on the rear of a yard engine at night, except when it has a headlight at each end.

Season's Work.

General improvements, tile drainage, reballasting, etc., can best be carried on from late spring to late autumn, but all such work should be planned beforehand, so that the track may not be disturbed for reballasting just after the section gang has completed surfacing. Work trains and floating gangs for ditching, ballasting, widening cuts, etc., and special gangs on new interlocking plants, rearrangement of yards, repairing or building structures, etc., may be worked at any time from the end of one winter to the beginning of another. For the ordinary work on the sections no set rules or program of procedure can be formulated, as the requirements vary in different sections of the country. In general, however, the year may be divided into four seasons, and the work done during these seasons practically as outlined below:

Spring.—As soon as the winter is over, all likelihood of snow past, and the frost coming out of the ground, the work of reducing and removing the shims should be commenced. The frost will, of course, remain longer in the roadbed in cuts than on exposed banks. Low joints must be raised, spikes driven, bolts tightened, cattleguards and road crossings cleared and repaired, ditches cleaned, fences repaired, portable snow fences taken down and piled, rubbish and old material cleared from the right of way, and the necessary lining and surfacing done to put the track in good condition previous to the more extensive work later in the season. At the same time sign posts and telegraph poles are straightened, fences repaired, and sidetracks and yards overhauled. The gang (if not already increased) is then increased to its maximum number, and the work of renewing ties

is commenced, the ties having previously been distributed on the section. About four days a week should be devoted to this, all ties being fully tamped as soon as they are in place. The other two days are spent on other necessary work. On some roads the tie renewals are done quickly at the beginning of the season, while on others this work is spread out through the season. The former is by far the better plan. The work of thorough lining and surfacing preparatory for the heavy summer traffic is then commenced. The lining is done first, on account of the bad line resulting from the tie renewals, but the surfacing should follow very closely. The gaging is done at the same time. Ballasting is done after the new ties have been put in.

Summer.—Surfacing and rail renewals may be done at any convenient time between spring and winter. The new rails are sometimes laid before the ties are renewed, but it is better to put the ties in first and have them thoroughly tamped up, especially if there are many bad ties. A general inspection of spikes, bolts, nuts and nutlocks is then to be made. All worn, bent, broken or improperly driven spikes are removed, the holes plugged, and new spikes are driven. Broken or loose bolts are replaced. Switches and switch connections, frogs, guard rails, etc., need to be carefully inspected and repaired. As fast as the regular surfacing is completed, the ballast should be dressed to the standard cross-section, and the toe of the slope lined to a "grass line" about 5 ft. 6 ins. from the rail. Tile drainage, correction of signs, and general work not interfering with the track itself can best be done during the summer. Spare time can also be spent in trimming up yard tracks, and clearing yards and station grounds.

Autumn.—Weeds should be cut at least once a year, and the best time for this is just before seeding. The grass on the right of way should be mowed, bushes cleared and trimmed, and in cases where fires cause trouble a fire guard may be formed by plowing a narrow strip about 50 ft. on each side from the track. Burnt or decayed trees likely to fall near the track should also be removed, and the dry brush, old ties, etc., may now be burned. Old material should also be cleared up. About a month before the commencement of the winter or rainy season, a general surfacing, lining, gaging and dressing of the track should be done, starting at the farther end of of the section and working steadily to the other end. The track itself should be put in condition at the same time, and the spikes and joints seen to. When this is done, ditching must be undertaken, the ditches being cleaned out and improved where necessary to give the necessary width and grade. The more thoroughly this work is done the better will the track be during the winter. Trenches should also be cut under switch rods to prevent water or snow collecting around them and freezing. The culverts and waterways must then be cleared of brush and obstructions, and any signs of scour or undermining looked for, while streams should be examined above and below the culverts and any obstructions removed. After this there is plenty of work to be done in cutting and burning weeds, repairing fences, repairing and erecting snow fences and stacking additional portable snow fences where they will be needed. Track signs and telegraph poles have to be inspected, and cattleguards and crossings cleaned up. Yards and sidetracks may profitably be cleaned, drained, leveled up and repaired before the snow falls.

Winter.—The winter work, with reduced track forces, is largely that of inspecting the track and making small repairs. Such work will occupy the time between snow storms or in fine weather. During snow storms, the switches, frogs and guard-rail flangeways must be kept clear, as also all signal and interlocking connections. Salt is used to melt the snow, but oil should afterwards be supplied to all moving parts, such as slide plates, bell-crank levers, etc., as the salt water has a tendency to rust the iron, making the parts move hard. In heavy snow storms, the section men must work in clearing the track and help the snow gang or shovelers. During fine weather, rails, ties, lumber, fence material, etc., may be distributed, ready for spring work. Heaving of the track by frost has now to be expected, and proper precautions must be taken to keep the track in surface by shimming. The ditches should be examined as soon as any thaw sets in, and kept clear of ice or packed snow, so as to allow free passage for the water.

Lining.

The true alinement of track is essential for economy of maintenance and for the easy and safe running of trains. Even slight kinks in tangents or irregularities on curves cause an unpleasant side surging motion of the cars, which in aggravated cases may even lead to a derailment. All kinks of rails should be taken out with the rail-bending machine, and all rails for curves over 2° or 3° should be bent in this machine, care being taken to have the ends bent uniformly with the body of the rail, which is not always done.

The foreman sets his gage on the track at each center stake, and the men throw the track by means of bars until the center mark on the gage is over the center tack in the stake. In lining track after surfacing, the lining bars must not be stuck in the ground at too great an angle, or they will raise the track in moving it, and so spoil the surface. If the track is hard to move, all the bars should be stuck firmly in the ground, so that none of them will slip, and then all the men should pull steadily together as the foreman gives the word. When this has been done at four or five stakes, the men go back and throw in the intermediate points, the foreman lining them in by his eye. When the road is in operation, the track centers soon become destroyed or displaced, and the effect of the traffic is to cause the track to shift more or less both on tangents and curves, and especially at the ends of curves if transition curves are not used. If the foreman's eye alone is then depended upon for lining, there will gradually develop considerable changes from the original alinement, including modifications of curves and swings on long tangents, since no trackman's eye is sufficiently good to run in curves or long tangents unassisted by an instrument. The varying ideas and ability of individual men will thus result in giving a line which is not satisfactorily true.

In any thorough realinement of a piece of track, the transit should be used, and the track centers marked by tacks in stakes, as in new work. For double track, the foreman may have a special gage for lining the inside rail of the second track from the track already lined, all measurements being made from the gage side of rail heads. Center stakes should be set every three or four years, and those on sharp curves tested once a year. Iron plugs, 24 ins. long, may be used for curve centers, while in

some cases permanent monuments, consisting of granite blocks or posts, are set at the P. C. and P. T., or around the curve, from which remeasurements can be taken to check the alinment.

For the ordinary lining work on the section, the foreman's eye is mainly relied on, but a careful man will assist his sight by means of a sighting rod or target. For short sights, as in bent rails, he should bring his eye close to the rail, but for longer sights he should stand up at some distance from the work, so as to avoid putting a swing in the track. He may sight by means of a rod or target fitted to a track level or gage, a graduated arc on the gage giving the vertical setting of the rod. The target is screwed into the top of the gage, with its center line directly over the gage side of the rail. In all work of this kind, one line of rail is taken as the "line rail," and all lining is done on it, the other rail being conformed to the line thus given in the subsequent operation of gaging. After proceeding ahead for some distance the foreman should turn and sight back as a check upon the accuracy of his work.

Bad "swings," should be lined in by a transit. With sights of 1 to 5 miles, as on long tangents, the center line may be sighted from the transit upon

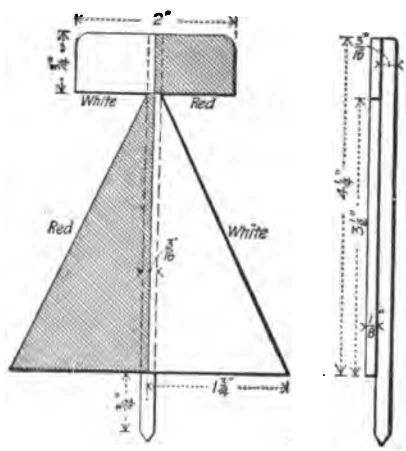


Fig. 205.—Track Target for Lining Curves.

a foresight target 36 × 18 ins., painted red and white, and placed over the track at a water tank, etc., at a sufficient height to clear trains. Center stakes and tacks may then be put at intervals of about 750 ft. (or opposite every fifth telegraph pole). The transit is then placed over the gage side of the line rail at the starting point, and a foresight taken on a rod set at the gage side of the rail and attached to a track gage, whose center line is over the center tack of one of the stakes. Intermediate sighting is then done on a small target on a second track gage, which is moved along about 50 ft. at a time. A lining gang for this work would consist of about three men ahead of and five behind the moving target. A useful backsight target to expedite transit work in lining curves, etc., in maintenance-of-way, is shown in Fig. 205. It is driven into the stake or tie just back of the tack marking a point, and its use saves the time otherwise lost by the

whole party, when a man is sent back with rod or pencil to give a back sight. Three men with a few of these targets can work as fast in rerunning curves and tangents, as four men without them. They give a well-defined sight, even at long distances, and stand so low that passing trains do not knock them out. A smaller and cheaper target is of ⅛-in. iron, of triangular form, 2¾ ins. wide on top, and 4½ ins. high (including a ½-in. point which is driven into the tie.

A curve should be maintained uniformly at its proper degree from end to end. Continual lining and work, or neglect, very often results in sharpening a curve at various points, so that a nominal 10° curve may vary from 5° to 15° and will consequently ride very badly. The curves should be tested periodically with the transit, and the foreman should also check them. To do this a cord is stretched tight with the ends touching the gage side of the head of the outer rail, and the distance from the middle of the cord to the rail head is carefully measured. This distance in inches divided by the middle ordinate for a given length of chord of a 1° curve gives the degree of the curve tested. The middle ordinate for different chords (or measured strings) for a 1° curve are given in Table No. 22. With a 62-ft. chord, each inch of middle ordinate represents 1° of curve.

TABLE NO. 22.—MIDDLE ORDINATES FOR CHORDS OF VARIOUS LENGTHS.

Length of chord.	Middle ordinate for 1°		Length of chord.	Middle ordinate for 1°	
30 ft.	¼-in.	0.25	62 ft.	1 in.	1.00
44 "	½-in.	.50	100 "	2⅝ ins.	2.625
50 "	⅝-in.	.625			

This table also gives the necessary ordinate for bending rails to a curve of given degree, as described under "Bending Rails." In lining curves in regular section work, the foreman takes a cord 62 ft. or 100 ft. long, and at a part of the curve which seems to be true he measures chords along the gage side of the outside rail (or outside of inner rail if the rails are worn), and measures the middle ordinate. Having thus ascertained the middle ordinate, or having obtained it from such a table as Table No. 21 or 24, if he knows the degree of curve, he commences at the point of curve (or point of circular curve if there is a transition curve) and measures chord lines from each middle ordinate, thus getting ordinates at intervals of 31 or 50 ft. These should be recorded on a slip of paper or on the rails, and when the entire curve has thus been checked it may be lined to give the proper uniform ordinate all around. The outside rail should be taken as the line rail, beginning some distance back on the tangent, if this is not the line rail on the adjacent tangent. This rail should be thoroughly spiked, so that it will remain in position for lining the gage rail. When the curve has been checked, the ballast should be cleared away from the ends of the ties on the side to which the track must be thrown in correcting the line. The lining should be done before the surfacing. (See also Chapter 20.)

Gaging.

This is done immediately after the lining, and consists practically of lining the "gage" rail by measurements from the "line" rail by means of a track gage and level. The lugs or stops at one end of this gage are brought tightly against the latter rail, the gage rail being then moved to bear

against the lugs at the other end. The gage rail is firmly spiked as fast as it is set in position, and as the line rail has already been securely spiked both rails are held firmly to the ties in readiness for the work of surfacing or raising track, which is the next operation.

Surfacing.

This work is almost continually required for track maintenance. A common and troublesome cause of bad riding track is an irregular surface, with sags, low joints, bent rails, and short depressions and humps in the roadbed. These defects are due to heavy loads and traffic, light rails, weak fastenings, poor ballast, insufficient tamping, rails out of level transversely on tangents, and generally faulty or insufficient work of maintenance. The remedy for this is surfacing, or putting the rails and track in a uniform plane. In the general surfacing done each year, the track should be raised only just enough for proper tamping, to bring up the low parts to a uniform surface, the track being raised out of a face only every four or five years. Great care is required to prevent the sectionmen from raising it too much. No raise must be made in tunnels or under structures with a headway of less than 22 ft. In stone, slag or coarse gravel, a thorough tamping can rarely be done without raising the track about 1 in. In sand, earth, cinders or poor gravel, a raise of ½ to 1 in. may be made by tamping without disturbing the bed of the tie. This work should be done immediately after tie renewals in the spring, and attended to again before the winter. It should also be looked to immediately after the laying of new rails, so as to prevent the rails from being surface bent by trains running over them when they are not uniformly supported, as it is almost impossible to take out such vertical kinks. When new rails are laid, the track should be raised enough to allow all ties to be tamped to give an even bearing. The freezing of water in the ballast or roadbed in winter causes "heaving," the effect of which is to raise the track irregularly. As the frozen ballast cannot be tamped, shimming or blocking has then to be resorted to in order to bring the track to surface.

The track level and gage should be frequently used in surfacing, and no foreman should be allowed to work under the idea that his eye is superior to an instrument. The track level, however, merely indicates local defects in surface, and there is, unfortunately, no instrument in general use which will show the general condition of the plane of the surface. Certainly no eye can detect a general irregularity in this plane, in the same way that it can detect a general irregularity of line in the shape of swings, etc. The only way is to sight one rail into a uniform plane, and then to bring the opposite rail up to the same plane by means of the track level. As proper surfacing and superelevation can only be given with a correct spirit level, this tool should be reversed occasionally on a level piece of track to see that the bubble is always in the center. If not, the level should be sent to the shop for repairs. The best way to put track up to surface is to use a sighting board and blocks. The board is about 10 or 12 ins. wide, long enough to rest across the rails; and it is painted black, with a white line, say 4 ins. from the bottom. This is placed on the rails at a point beyond the part to be raised, where the track is already in proper surface. The foreman has a wooden block, 4 ins. high, which he

places on one rail at a point three or four rail lengths on the other side of the part to be raised. A similar block is placed on the rail between the board and the first block, this second block being moved from point to point and the track raised at each point until the top of the block is sighted by the foreman in line with the first block and the stripe on the board. This fixes the surface of only one rail, and the other side of the track must then be brought up to the extent shown by the track level. The usefulness of this method of sighting, may, however, be extended by having the two blocks (or targets) each mounted on the middle of a track level, the sighting showing the longitudinal surface, and the level bubble showing the transverse surface. The raising is done by bars or jacks, the latter being preferable if the raise is sufficient to allow of their use.

In surfacing or raising, the track should never be brought up above the level of grade stakes or of bridges in the expectation that the traffic will settle it down to the exact grades. If the raise is at all heavy, the joints are raised first, then the centers, and then the quarters; but if it is light, the joints are raised first, and then the thirds or "long quarters," which will bring the centers up properly. The track level is then used at all joints and centers, and the opposite rail brought up as required. The raise should extend only over such a length of track as can be tamped between trains, and neither side should be fully tamped until both sides have been brought to surface. In surfacing on curves, the inner or lower rail is taken as the sighting rail. The work of lowering humps or high places to surface is more troublesome, and it may be necessary to shift the ties. In this case the ballast is shoveled out between ties 1 and 2, 3 and 4, 5 and 6, etc., and ties 1, 3, 5, etc., are shifted into the spaces thus formed. The beds of these ties are then leveled off as required, and the ties shifted back into position; ties 2, 4, 6, etc., are then knocked into the space dug out, and have their beds leveled off in the same way, being then put back into position. The ties should be well tamped, and the lowered piece of track tested for surface after some trains have passed over it.

With earth or mud ballast, the section gang has to be continually at work surfacing, as the material will not give a uniform support under traffic, but some parts will go down while others remain firm. If the force is sufficient the track should be surfaced and tamped in the usual way; but if the section is long and the number of men allowed is small (which is frequently the case on such roads), then there is not time enough to fully tamp all low ties and low spots to proper surface. In such cases the tamping must be done partly from above by the trains, instead of merely from below by the tamping bar. The jacks or raising bars are put under the part to be raised, as far from the finished part of track as is possible without causing the rail to sag between the jack and the finished track. The low track is then raised above the finished or desired surface by an amount varying from ¾-in. for small lifts to 1½ or 2 ins. for lifts of 4 to 5 ins. Earth is then shoveled under the ties and packed by the shovel blades, and by bars or shovel handles at the joints. The jacks are then removed, the track sighted for surface, and rectified if necessary. The track should be lined up before the first train passes. The train will drive the ties down to surface, and after it has passed the surface should be finally sighted, and the ballast then well shoveled under the ends of the ties tamped and dressed to

shape for proper drainage. The best surface will be obtained if one man does all the filling, as no two men will fill in alike. The foreman is the best man to do the filling, as he should observe what parts of the rail require the most raising. In work under such circumstances it is simply a question of how to keep the track in reasonably good running condition, without regard to appearances. In all such cases, however, good men who are familiar with the work will devise many useful little plans for themselves, while new men, accustomed, perhaps, to good ballast and large gangs, will find it difficult to get satisfactory results under the new conditions.

Mention may be made of the Patterson surfacing machine, which has been tried experimentally and is intended to do away with tamping, as this necessarily disturbs the old bed of the tie to some extent. A blower driven by hand is mounted on a frame which runs on one rail and is clamped to it when at work. The machine consists of two vertical pipes, one connected with the blower by a hose, and the other having a hopper on the top for the ballast. The pipes unite in a shoe at the bottom, and to this is fitted a thin flat horizontal nozzle with variable width of opening. The material used is screened stone or gravel not exceeding ¾-in. in size. The ballast is cleared away from the ends of the ties and the track raised to surface by bars or jacks. The nozzle is then inserted under the end of a tie and the blower put in operation, driving the fine material into all the cavities and packing it solid. This method can be used for a raise of ¼-in. to 1¼ ins. In a test on the New York, New Haven & Hartford Ry., a gang working in the usual way surfaced 5 ft. per man per hour, while with the machine the average was 8 ft. In one year, the stretch surfaced by hand required 36 hours labor for maintenance, while that surfaced by machine required only 2 hours.

Renewing Ties.

The new ties are usually distributed by work trains at convenient times during the winter, so that all may be on the ground soon after the frost is thoroughly out of the roadbed. The distribution is done under instructions from the roadmaster or foreman as to the places for unloading and the number unloaded at each place. For small lots or during a dull season, the ties may be distributed from local freight trains. In some cases the ties are not distributed along the section from the cars, but are unloaded in lots at certain points and thence distributed by push cars. The old ties to be renewed should have been previously marked conspicuously by the roadmaster, and only ties so marked must be removed. The work should be done before or immediately after new rails are laid, so as to give a good substantial bearing to the rails, all new ties being thoroughly tamped. Old joint ties may be left under new rails if they are sound and of suitable size, but all old ties left in the track should have open spike holes plugged. The work should be commenced as soon as possible after the frost has left the ground, as the ballast is then loose, while the men can work to better advantage than in the summer. Then by the time the heavy summer traffic begins, the new ties will have become well settled, and the track will have a substantial bearing, and will require but little maintenance. If the ties are put in late, and the season is wet, they do not get properly tamped, so that they may have to be shimmed in the winter; the renewal of

shims and fixing up of the roadbed in the spring then delays the new work of tie renewals. When the work is once commenced it should be pushed steadily along and completed as soon as possible, for continual renewals of a few ties at a time all through the season prevent the track from being well settled and consolidated. This continual disturbance results in an increase in maintenance expenses and train expenses.

Gravel ballast is cut away from the ends of the ties and loosened along their sides. The spikes are then drawn, and the rails raised by jacks just enough to allow of the old tie being knocked out and a new one slipped in on the same bed. The ballast should not be dug out under the tie, unless the new tie is of greater thickness (which it should not be), as the less the tie beds are disturbed the better for the maintenance of the track surface. This general rule may, however, be modified where only one or two ties are to be renewed in a rail length, but in this case a loosening of the side of the tie bed will usually enable the old tie to be taken out and the new one put in without much disturbance of the bed, and without the disturbance of the adjacent track which is incidental to raising by jacks. With stone, slag, or coarse gravel ballast, which is liable to fall onto the tie bed when the tie is removed, it is necessary to dig out the ballast at one side of the tie, and to knock the tie sideways into this trench. Some foremen prefer this plan with earth or common gravel, but the amount of digging required is liable to disturb and loosen the ballast. This plan may, however, be employed when two adjacent ties have to be renewed. If the ties are not uniform, the larger ones should be selected for the joints and for curves; and the wider end should be placed under the outer rail on curves. The ties should be properly spaced, placed square across the track (or radially on curves), and their ends should be lined at one side of the track. It is rarely economical to turn old ties, except where tie-plates are to be applied, and then it is probably better to turn the ties than to adze out new seats on the old worn faces.

If the traffic is heavy, each tie should be tamped and have the outside spikes driven at once. Otherwise, a number of ties may be renewed in succession; one man going ahead to cut the earth or gravel from the ends of the ties, two men pulling spikes, and two men raising the track with jacks. If only one jack is to be had, the rail first raised should be blocked up, and the jack then put under the other rail. When 20 or 30 ties have been thus put in, three men are sent back to do the spiking, one holding up the ties with a bar and two driving the spikes. The new ties should be tamped each day as put in, the tamping being done thoroughly with a bar or pick. The ballast is then filled in between the ties and dressed to proper shape. If the new ties are shovel-tamped, or only partially tamped with bars, and then left to be finished a few days later, the old ties will be disturbed, and a soft spot probably caused, especially if rain falls before the tamping is done. No train should be allowed to pass over untamped track, the foreman taking it for granted that it is safe.

At the end of each week the ties removed should be properly piled on the right of way, at a convenient distance from the track if they are to be loaded on cars, or midway between the track and the fence if they are to be burned. They should not be left in the ditches or scattered about the right of way. Ties may be burned in small piles of 5 to 10, or in large

piles of 50, but the former is usually the better and safer plan. The piles should not be near the track, as the intense heat is injurious to the paint and varnish of cars. Large piles should be burned in damp weather to reduce the danger from fire, and in all cases the burning piles should be watched to prevent fire from spreading to fences, fields, etc. The cost of renewing ties in New England is estimated at 17 to 21 cts. per tie in gravel, and 30 to 35 cts. in stone ballast. This includes all work from the time the new tie is delivered on the section until the old one is piled ready for removal or burning. The cost of piling the old ties is 1 to 2 cts. per tie.

Adzing and Spotting Ties.

When ties have been badly cut by the rails, the rail seat must be cut level with an adze, in order to form a proper bearing for the old or new rails, or for tie-plates. The trackmen have usually to rely upon their eyes in getting a level and even seat, and while practical men are very expert, yet as the ties are more or less covered with dirt and sand, and the men are hurried, the work is very often imperfectly done. If the foreman should take time enough to ensure the work being well done, he is liable to be censured for getting so small amount of track laid. Mr. G. M. Brown, when Chief Engineer of the Pere Marquette Ry., invented a machine for grooving the ties to the required depth, the grooves forming a gage or guide to the men in adzing the ties. A frame projecting in front of a flat car and supported an axle with 20-in. wheels, has a shaft on which are four sets of saws cutting four grooves about 2½ ins. wide. The depth of cut can be regulated by a screw. The shaft is driven by an engine on the car, and the frame is raised by a derrick on a car in front in order to allow the saws to clear the rails at turnouts, etc.

Setting Tie-Plates.

Tie-plate gages have been described in Chapter 13 (Track Tools). In preparing to lay tie-plates on the Buffalo, Rochester & Pittsburg Ry., many spikes are withdrawn, and as much adzing is done as possible before the rails are moved. When the traffic permits, the rest of the spikes are withdrawn, the rails are thrown out, spike holes plugged, and seats adzed and leveled. The men work in gangs of three, one to set the gage and place the tie-plate in position, the other two having wooden mauls weighing 16 or 18 lbs., with ordinary spike maul handles about 36 to 38 ins. long, to drive the plate down so that its flanges or claws will have a firm hold in the wood. When a sufficient number of plates have been thus set, one of the gangs can be sent back to throw in the rails and spike them, the spike holes in the plates giving the proper gage. A lighter maul may be used, if its face is large enough to cover the tie-plate, but some men prefer an even heavier maul. If the plates have longitudinal flanges, the first blow at least should be struck from a position at right angles to the flanges.

Considerable economy in track work may be ensured by placing the plates on new ties for renewals before the ties are put in the track. This can be done by the section men in bad weather or during the winter. In using the tool, Fig. 179, for this purpose, the adjustable head (C) is clamped in such a position on the bar that tie-plates of the size to be used will be in position for the proper gage of track when they are set with their ends

butting against the faces (F) and (G). When set in this way the flat blades of the two heads will fit on the seats for the tie-plates. The tool is then set on the tie to test the surface of the seats, and these are then adzed or dressed as required to give an even and level bearing. The tool is then turned over and set with the faces (F) and (G) resting on the tie, and one plate is put in position, being gaged and squared by fitting against the face (F) and the blade (B). This plate is then set by means of the wooden mauls, when the tool is put back in the same position, fitting against the plate, and the second tie-plate is then placed and set in the same way. The tool is frequently used for testing the level and surface of the rail seats of the ties when tie-plates are not to be used. The several operations are effected easily and rapidly.

Tamping.

The only way to maintain track in good surface is to have the ties well and thoroughly tamped. Tamping picks are used for stone, slag, or coarse clean gravel; tamping bars are used for earth, cinders and ordinary gravel. In tamping with bars there should be an equal number of men on each side of the tie, standing opposite one another and striking in unison, so as to pack the material fairly and not drive it out at the opposite side of the tie. Shovel handles make fairly good substitutes for bars in light work, or where the extent of the work and the smallness of the gang prevent thorough hard tamping. Shovel blades, however, should never be used for tamping, except at the middle of the tie in loose ballast, as the shovel has not the force or weight necessary to pack and consolidate the material sufficiently for good substantial work. This may be stated very emphatically, though many trackmen working in gravel or earth ballast believe otherwise. The joint ties should be tamped first, and then the shoulder ties, both somewhat harder than the others, but never tamped higher, as that will cause the traffic to crack the splice bars. The object of tamping the ties next to the joint ties with extra care is to prevent the upward deflection of the joint when a wheel is over the second tie, which deflection often causes the splice bars to crack downwards from the top. The most thorough tamping should be directly under and for about 12 or 18 ins. on each side of the rail, and tamping from the ends will assist in getting a good firm bearing under the rail. Each tie should be fully and properly tamped before the men leave it. On old track, the middle of the tie should not be tamped too hard, or the track will have a tendency to rock laterally, and the ties may be broken. When the track has once become center-bound in this way it is difficult to effect a remedy without disturbing the entire track, involving considerable work and expense. On new track, the tie can be tamped for its entire length. The ties at frogs, switches, crossings, etc., should be specially well tamped. Tamping machines have been tried.

Raising Track.

About once in three to five years the entire track will be required to be raised out of face or brought up to a new surface. At such a time (as well as in raising out of sags of any considerable depth) grade stakes should be set to give the elevation of the top of the rail. (Chapter 17). Ballast should then be distributed for raising the track. When in raising

track (or changing grades), where good expensive ballast is used, there would be 6 ins. greater or less depth of ballast under the ties than the standard depth, then the roadbed should first be raised by filling (or cut down), so as to retain a practically uniform depth of ballast and so prevent the waste of ballast as filling.

In raising, jacks should be used under each rail, and both sides of the track brought up and tamped simultaneously; it is bad practice to raise and tamp one side first, and then bring up the other side by the track level. The raise should not exceed 6 ins. at any one lift, the 6 ins. of ballast being well tamped, and then another raise made. The jacks should be set about 2 ft. from the joints, so as to bring them up level and avoid bending the splice bars. They should never be set on the inside of the rails (see "Tools"). The track may be raised about ½-in. or ¾-in. above grade (according to the quality of the ballast) and well tamped, on account of the tendency of new track to settle: Every foreman has his own ideas as to the proper course to pursue in tamping a raise, but a good plan is to first tamp the joint and shoulder ties, then the center tie, the two quarters, and the intermediates; finishing off again at the joints. An incline or "run-off" should be made, connecting the old with the new level, this being long enough to allow trains to ride easily over it, and to prevent the bending of the rails. If the work is extensive and the section gang is assisted by a floating or work train gang, a part of the regular gang should follow behind the raising gang, to finish the tamping, surfacing and dressing.

Moving Track.

In building additional tracks or improving alinement, it may be desirable or necessary to shift the existing track to another part of the roadbed. This may be done in either of three ways: (1) Tearing up the track and relaying it on the new location; (2) Sliding the track bodily in sections; and (3) Throwing the track with bars or by machine. Considerable work of this kind has been done in the four tracking of the New York, New Haven & Hartford Ry. In one place, where the new roadbed was 6 to 9 ft. above the old one, the two old tracks were shifted bodily 20 or 30 ft. on skids to the new roadbed, the old bed being then raised by filling to correspond with the new grade. The length of this stretch of track was 8,930 ft., including two bridges, at which the track had to be cut. On the open line, the track was cut at lengths of five rails by unbolting the splices; planks were then spiked to the ties to keep them properly spaced, and each length of track was then slid laterally on six skids made of rails spiked to spruce stringers, 6 × 8 ins. The force aggregated 260 men distributed as follows: 1 foreman and 35 men first raised the tracks ready for skids (using six jacks to a five-rail length), and drew all spikes from worthless ties, so as to leave them behind and avoid handling useless material; 1 foreman and 150 men then moved the lengths of track by block and tackle to the top of the new bank, unloaded ballast and roughly surfaced the track; 1 foreman and 75 men then made the connections between the lengths and lined and surfaced the track. A work train ran back and forth distributing material. The skidding and lifting by the second gang averaged about three minutes per length of track. Work was commenced at

7 a. m., and the track was turned over to the operating department by 5 p. m. The second track was afterwards moved in the same way. The initial cuts were made where the new bank was only 2 ft. above the old bank, and the end pieces of track between the undisturbed track and the first lengths to be moved were thrown to the new alinement by lining bars. In some cases, owing to the curves and bridges, some of the five-rail lengths had to be moved longitudinally, even as much as 3 ft. For this purpose the skidding gang of 150 men had 75 bars; these were placed horizontally under the rails and held by a man at each end of each bar. The section of track was thus readily raised and moved forward or backward by easy movements. The lengths on the bridges were left until the last, the spikes being then drawn and the rails carried over and spiked to the floors of the new structures.

Under ordinary methods, the spikes would have been drawn, rail joints disconnected, and ties and rails carried about 25 ft. and relaid in the new position, as in new tracklaying. This would involve much more delay, and some considerable loss and breakage of bolts and spikes, though this might of course be reduced by carefully planning and laying out the work, in the same way as was done for the "skidding" method. On the other hand, the skidding is likely to result in surface or line kinks in the rails, bent splices, and displaced spikes, making it difficult to put the track in proper condition for service in its new location. If the track is for only temporary use, or for work trains, as on parts of the work above described, the skidding method may be adopted to advantage. For permanent work it would be better in the end to build the new tracks complete in the usual way, then make connections with the old tracks at the ends, and abandon the old tracks, which can then be removed and the roadbed improved or rectified as required.

It is sometimes considered that for a short move it is most economical to throw the track by means of lining bars. Stakes should be set for the new alinement, and driven so as to be below the base of rails. The length of rails on the new and old alinement should then be carefully measured with a steel tape, so that rails may be cut to fit if there is any difference. The new grade should be leveled and ballasted, the ballast being given an incline on curves, so that when the track is thrown it may be at once ready for traffic. If the track is to be thrown for a distance less than the length of a tie, then the part of the old roadbed which will be included in the new bed should be dug out below the ties. If the distance is greater, this need not be done, but the ballast should be loosened between the ties. where the rails are cut, there should be six men (three cutting and three drilling). Having first disconnected the rails and moved the spikes on the side opposite to that towards which the track is to be thrown, two or three gangs working one behind the other, should throw the track, not moving it more than 12 ins. at each throw, so as to avoid bending rails and splice bars or twisting the ties. Other gangs should follow with the lining and surfacing as soon as the first part of the track is in its new position, but before the tamping is done, two or four men with sledges should tap the ties to proper spacing and square with the rails. Trains should be flagged to pass slowly over the new track until it is thoroughly finished and in substantial condition. The work may be done at once, in a time of light

traffic, or gradually (between trains) during the week; proper curve connections being maintained at each end and all trains being flagged. The Creese track throwing car is a heavy flat car with a stout 30-ft. pole projecting from one corner and carrying a wheel which runs against the web of the opposite rail. The pole is adjusted to position by a hoisting cable and turnbuckles and stiffened by braces against the car. It can throw or shift the track 6 to 36 ins. It has been used on the Pennsylvania Lines and the Baltimore & Ohio Southwestern Ry.

Handling Rails.

There is probably no one thing about which the average track foreman complains more bitterly, or which is more often offered as an excuse for rough-riding track, than kinked and surface-bent rails. One of the causes of these defects is the way in which the rails are unloaded. Rails should not be dropped or thrown from the side of the car upon the roadbed; and if they are necessarily thus dropped, care should be taken that they are dropped on soft, level places, and so that they do not strike ties, boulders or other rails. If unloaded from the end of a car, the rail should not be allowed to slide off and drop upon ties. Neither should they be unloaded from a moving train, except in cases where the train moves ahead a rail length at a time and its motion is used to pull off the rails.

In unloading from the side of a car, the rails may be unloaded at one place in a pile, by means of skids, and then distributed to the required points on push cars. The skids may be two rails or two oak sticks, about 3 x 4 ins., 6 to 10 ft. long, faced with iron and having each a clamp at the upper end to fit on the side of the car. The skid may have a small pulley set below the face at the upper end, a rope passing around this and having a hook at one end to sustain a rail. Two men on the ground lower the rails by these ropes and also shift the skids as the train moves ahead. The rails may also be lowered at the side of the car by means of three brackets or straps hooked onto the side of the car, each bracket carrying a horizontal roller at its lower end. The length of the brackets is from 5 to 18 ins., the shortest being at about the middle of the car and the longest near one end, so that the three together form an inclined roller-way along the side of the car. Men on the roadbed receive the end of the rail and lower it, not allowing the rail to drop.

In unloading from the end of a car, the rails may be simply pushed off the car, or hauled off by a rope. The rope (or chain) should be 15 ft. long, having an L hook at one end and a claw hook at the other; the L hook is put through the bolt hole of a rail on the car, and the claw hook placed over the edge of a tie. The train then moves ahead and the rail is thus hauled off. Two men attend to the ropes, and there should be men to lower the free end of the rail. Sometimes 6 men (or 8 for long rails) are on the car, and with tongs slide the rail off, while 8 men on the track haul the projecting end outside the track until it rests on the ground, when they move up to the car and take hold of the other end, which they carry out in the same way, laying the rails either upon the ground or upon the ends of the ties. The men should not be permitted to drop the end of the rail, but there is some liability of injury to the men, owing to carelessness or accidental slipping causing them to drop a rail. To prevent improper

handling of the rails it is a good plan to have a tail gate attached to the end sills, forming an inclined plane, the lower end of the gate resting upon the rails. With gondola cars a second shorter gate may be attached to the top of the end of the car, having its lower end resting upon the longer gate. The rails may be pushed off by forks or hauled off by ropes as the train moves ahead, the end of the rail having a continual bearing on the gate until it reaches the ties. In this way the work can proceed quickly, without danger to the men.

In unloading by hand, with a train of 12 to 14 cars, two unloading gangs of 8 men each may be employed. At the first stop, the gangs work from the ends of the train, throwing two rails off each car, until they meet at the middle car. The train then moves ahead one train length, and the two gangs work from each other to the end cars. In unloading rails of greater length than 30 ft. a larger number of men must be employed, but not a greater number per ton, and no more than is generally available. The Norfolk & Western Ry. finds no difficulty in handling its 85-lb. rails, 60 ft. long, only a few more men being required. Ordinary gondola or flat cars will usually suffice for carrying rails 30 ft. long, but flat cars should have 3-in. end planks to prevent the load from shifting. The Lehigh Valley Ry. loads its 45-ft. rails on two 30-ft. cars. The Norfolk & Western Ry. loads its 60-ft. rails on alternate flat cars, the ends projecting over the other cars, requiring 7 cars (35 ft. c. to c. of couplers) for three loads of 34 rails each.

At yards and mills a pneumatic hoist may be used to advantage. This consists of an inverted cylinder about 6 ins. diameter and 48 ins. stroke, hung from the end of a horizontal revolving crane arm or from the end of a derrick boom. A pipe connects the cylinder with a compressor (an air-brake pump being frequently, though not economically, used for this purpose), and the operations are controlled by a three-way cock on the crane post or derrick mast. To the end of the piston rod are attached suitable chains or slings.

Renewing Rails.

In laying new rails on a section there are two principal methods of practice. One method is to lay the new rails along the ends of the ties, to fully bolt up the joints, and then to take up the old rails and throw in the string of new rails. The other method is to lay in one rail at a time. There is also a compromise method, by which the rails are bolted together in lengths of five or six, the intermediate joints being left open, to be bolted up when the rails are in the track. In either method, the details of the work and the distribution of the men depend largely upon the traffic, and vary considerably on different roads. If the track can be given up to the roadway department, either entirely (as on a length of one track on double track roads), or for a certain time by arrangement with the superintendent or train dispatcher, the relaying should be done in a similar way to new tracklaying, the old rails being first removed and the new ones (distributed along the roadbed) laid in their place.

Laying Rails in Strings.—This method is not extensively used, and mainly where work is short, only small gangs available, the traffic only moderately heavy, and the work having to be done between trains. All the pre-

liminary work is done while the traffic is passing, and the rails then thrown in in strings as long as the intervals between trains will permit. One objection is the difficulty of insuring uniform expansion spacing, and much time is apt to be lost in properly connecting up with the old rail and adjusting the expansion spacing of the string of rails when in position. On curves, the new rails may be laid 12 ins. from the track rails; those for the outside of the curve being given more and those for the inside less expansion spacing than on tangents, at the rate of ¼-in. per 100 ft. length (that is for four joints), per degree of curve. The bolts should also be left somewhat slack, and the expansion spacing regulated and bolts tightened as soon as the rails are thrown into position. The joints between tangent and curve rails should be left open. The spacing may be maintained, or preserved from change, during the work, by having all joint ties in proper position and driving the spikes in the slots or at the ends of the angle bars as fast as each joint is reached. Usually only one line of rails is laid at a time, but both may be laid together if desired, one gang being 10 to 15 rail lengths ahead of the other, so as to avoid interference. In any case, the second line of rails should be laid as soon as possible after the first. Care should be taken to avoid bending the splice bars by hurriedly throwing the string of new rails into position with bars. The iron expansion shims should be left in place until the string of rails has been thrown into position, and should then be removed. Two men may do this work, one raising the point with a pinch bar to enable the other man to take out the shim. These shims should be L or angle-shaped straps of iron, 1½ ins. wide, of proper thicknesses, and those of different thickness (for different temperatures) should be kept separate. The use of wooden shims should never be permitted. On the Baltimore & Ohio Ry., where this system is used, the iron shims are marked with the temperatures at which they are to be used, and the foremen are provided with thermometers. The shims are put in when the joints are bolted up on the ends of the ties, and are left in place until the rails are in position. With care, very accurate work can be done, but it is considered that better results may usually be obtained by laying rails singly.

The first joint of the new string, at its connection with the old rails, will of course fit to place at once, a spike being driven at the heel to prevent the rails from being forced backward. Succeeding stretches, however, will not fit so closely, owing partly to variations in expansion and to slight variations in length of old and new rails. For this reason it is sometimes necessary to move a string of rails endways. A string of 20 to 50 rails can be moved by four to eight men, with bars placed at intervals of about six rails. They place the bars so as to get a bearing against the ends of the angle bars and pull together at a signal. If a work engine is available, a string of rails can be moved to place by the use of a 15-ft. rope or chain. The foreman (if near a telegraph office) should arrange with the train dispatcher to perform the work at times when it will least interfere with the movement of trains. He should then lay the longest stretch that can be properly taken care of in the time available, and have the track in shape before the next train is due. The work should not be done hurriedly.

Laying Single Rails.—If the traffic is very heavy, the most satisfactory

method, as a rule, is to lay a rail at a time, keeping the track all finished up behind the gang. This method requires a larger gang, as six or eight men are required to lift and move single rails, while two or four men with bars can easily handle a string of rails. The men in the larger gang also work somewhat at a disadvantage by being more crowded, but there is the advantage that every interval between trains can be utilized. This is the safer plan under such conditions, although if the traffic is exceptionally heavy, much time may be lost in disconnecting and connecting up for each move. Safety and good work, however, are of more importance than mere rapidity of work. A flagman (or two flagmen on single track) must be kept out all the time, while under the former method this is only required when the string of rails is being thrown in.

On double track, however, a certain length of track may be closed to traffic to allow of the work being done. This method, as carried out on the Boston & Albany Ry., is as follows: The rails unloaded from the work train are strung out along the ends of the ties by section men, all being placed with the brand outside. Care is taken to set the joints correctly, and to use occasional 28-ft. rails on the inside of curves to maintain the proper relation of the joints. The rails are then bent for the curves, and, if necessary, straightened for the tangents, it being found that from 20% to 50% of the rails in different lots require to be straightened. The splice bars, bolts, nuts and spikes are properly distributed, and the ties are adzed as far as possible at the rail seats. If tie-plates are used, this work will be greatly reduced, but if the new rails have a different width of base from the old ones, necessitating the removal and replacing of the plates, then new seats should be adzed for the tie-plates. A large force of men is now employed to cover the greatest length of track that can be dealt with at one time, the track being closed to traffic meanwhile. From 3 to 5 miles is a fair day's work, varying with the number of switches, but 8 and 10 miles have been relayed in a day of 10 hours.

With a force of 200 men, three gangs of 12 or 13 each are started pulling all the spikes except those on the inside of the right-hand rail. Each gang is subdivided into two gangs, the first having ordinary clawbars to start the spikes, and the second having goose-neck clawbars to pull them out. Then come the men who throw the old rails with crowbars, three or four men to each line of rails, the joints being unbroken except at long intervals. These are followed by 20 or 30 men who finish the work of adzing the rail seats, while 3 or 4 men of this gang have brooms to sweep chips and dirt off the ties. To remove old tie-plates and adze the rail seats where necessary will require about the same number of men as where no tie-plates are used. Then come the two setting-in gangs, 16 on each side, the 16 men lifting one 95-lb. rail with tongs and dropping it in place on the ties, while the foreman puts in iron spacing shims of the required thickness. Sometimes the rails are bolted up in pairs, in which case there are 32 men to each line of rails. These are followed by the strappers, putting on the splice bars, and bolting up each joint fully and tightly. The number of men in this gang will depend upon how well the nuts fit the bolts. If the nuts can be brought to a bearing on the splice bars with the fingers, 20 men will be sufficient, but if a wrench must be used to screw the nut all the way on, 40 men may be necessary. After them comes the spiking gang

of 30 men, working in groups of three, one man having a lining bar and the others spike mauls. The leading group works on the right-hand rail, forcing the rail home against the old inside spikes, and driving the new outside spikes. The other gangs, or "gagers," have each a track gage, and set and spike the left-hand rails to the proper gage. They also shift any ties that may have been misplaced, and tamp up or shim those which do not give a full bearing to the rail. The whole series of operations occupies about half an hour. A separate gang under its own foreman puts in the switches. The work train follows the men, its men picking up stray tools or supplies and seeing that the track is in safe and proper condition. When the work is complete, the track is again thrown open to traffic. After this, the section men unbolt the joints of the old rail, put the splice bars and bolts together, and throw the rails between the tracks ready for loading. The ties are also respaced as required, more or less of this work being always necessary, tie-plates are put on if required, and the track gaged and respiked. It is then surfaced and finally lined. As soon as the track has been laid by the relaying gangs, the rails are drilled for the bond wires of the signal system, and the creeper plates are put on.

The distribution with gangs of about 40 men in replacing 56-lb. rails with 75-lb. rails by this system on the Kansas City, Fort Scott & Memphis Ry., in 1895, was as follows: Handling rails, 12; pulling spikes, 15; spiking, 4; nipping, 2; flagging, 2; the balance bolting up the joints. When the men handling rails caught up with the spike pullers, they went back and put on the angle bars. While waiting for trains, the full bolting was done, old rails cut, and enough spiking done to make the break safe until the track was surfaced, after which the spiking was finished. Relaying rails with trains passing at intervals of a few minutes is close work, which is done on the New York Elevated Ry. There are 20 men to a gang, and they can unspike and unbolt an old rail, put a new rail in, bolt it and drive four spikes in somewhat less than four minutes. As to relaying with long rails, the Norfolk & Western Ry. has found it possible to lay 1,500 to 3,000 ft. of track per day with 60-ft. 85-lb. rails, without interruption to a heavy traffic. The force consisted of 10 men pulling spikes and throwing out old rails, 16 men putting in new rails, 4 men putting in joints, and 4 or 6 men spiking joints, centers and quarters. There was no appreciable difference in speed between the laying of 60-ft. and 30-ft. rails. The expansion spacing allowed was ⅝-in. at 0°, decreasing ⅛-in. for each 25° up to 100° F. The joint consisted of an outside angle bar and an 8-in inside fish plate with two holes, so that no inside spikes had to be drawn. Afterwards the Churchill joint was applied.

In removing spikes and in respiking there should always be left at least 4 spikes on the inside and 6 on the outside of each rail, and only half the spikes should be removed on curves. No train should be allowed to pass over a track that has less spikes than this, or has not at least the two middle bolts of each joint properly screwed up. If the new rails have the same width of base and head as the old ones, all the outside spikes should be removed, the inner spikes being loosened, so that the old rails can be lifted out and the new ones slipped in against the spikes. If there is a difference in the rail sections, however, the outside spikes may be drawn on one side of the track and the inside spikes on the other side, so that the new

rails can be spiked to gage. Three rows of spikes may also be drawn for this purpose. This work may be done by a special floating gang or by bunching several section gangs together. Each gang then renews the rails on its own section, lines and full spikes the rails to gage, lines and surfaces the track, tightens up all bolts and finally dresses off the ballast. Where the new and old rails meet, care should be taken that the heads are in the same line, gage and level. For small differences, an iron shim under the lower rail may be used, but for larger differences, a special joint is required. Where the new rails are heavier than those of sidetracks, they should be laid on the turnout and extending beyond the frog, so that the special joint will not come upon the switch ties. The rails must not be punched, nicked or slotted, as such marks are liable to cause fracture, but all holes made in the field should be drilled. Short rails are only admissible on the inside of curves (never on the outside) or as a temporary expedient on tangents, and no rail shorter than 15 ft. should ever be used in main track.

On curves, it is necessary to use a short rail at intervals in order to keep the joints from over-running, 26 and 28 ft. rails being frequently used. The total difference in length (in feet and decimals) of the inside and outside rails of the curve may be obtained by multiplying the constant 0.08552 by the number of degrees in the central angle of the curve (the minutes being either disregarded or reduced to a decimal of a foot). This total must be distributed over a suitable number of rails so as to avoid the use of one very short rail, and also to keep the joints as even as possible. A 30-ft. rail may be cut into two parts, differing in length by the difference ascertained as above. Then by laying the longer piece at the beginning of the outside line of rail and the shorter piece at the end of the inner line of rail, these will give broken joints on the curve and square joints at the ends. Another method is to allow a difference of 1.03125 ins. in length per 100 ft. for each degree of curve; or, in other words, to multiply 1.03125 ins. by the degree of curve and the number of hundreds of feet in the length of the curve. Methods of finding the degree of a curve in the track are given under "Lining." To change from even joints or tangents to broken joints on curves, the Northern Pacific Ry. finds the length of short rail on the inside by measuring from the center of the rail ½-in. for each degree of central angle of the curve.

It is usually required that the rails must all be laid with the maker's brand on the inside (sometimes the outside) of the track, to provide for possible defects in the rolls by which the sides of the head may be slightly unsymmetrical. Rails of similar section should be kept together, and this is specially to be observed in distributing old rails for relaying on third track, branch lines, etc. With old rails, this rule should not be observed where it will put a badly worn gage side against a uniformly worn gage side of an adjacent rail. Old rails for relaying should be sorted for height at the yards, and sent out in lots of the same height. They should be laid with the unworn side of the heads as the gage side.

In connecting the new rails with the old to allow of the passage of a train, or in finishing up work for the day, a 15-ft. switch rail should be used, being firmly spiked to place and having its surface slightly above

that of the old rail. After the new rails are laid, the string of old rails which has been thrown in to the middle of the track, may be unbolted and taken apart at leisure, all bolts, nuts, nutlocks and splice bars being carefully preserved. The old rails should not be left in the ditches, but placed beside the ballast or piled ready for loading onto the cars. Much of the work of renewing rails is done on Sundays, and many men believe this is necessary on account of the traffic. The work can be done, and is done, as well on week days, either between trains or by closing a length of track (on double track) to traffic. As already noted, Sunday should not be made an extra work day.

Shifting Rails on Curves.

On track having numerous sharp curves, the service of the rails may be considerably extended by transposing the inner and outer rails. The rails are disconnected to form strings of about 600 ft. in length (disconnecting the short rails on the inside of the curve). The strings are then thrown in and passed over each other. The stretches will have to be moved lengthwise, which can be done by bearing with bars against the ends of the angle bars, or by pulling with a work engine. The inside spikes should be drawn and in relaying to gage (on account of worn heads), the inner rail may be set in ¼-in., and the outer one ⅛-in., or according to the depth of wear of the side of the head.

Bending Rails.

On all curves of over 2°, the rails should be bent to the proper curve before being laid. If they are laid straight and then merely bent by spiking, the curve will be irregular (especially at the rail ends), and the rails will have a constant tendency to straighten. Bending rails by forcing, springing or striking with sledges should never be permitted. They should be curved in a proper rail-bending machine, and care taken to have the uniform curve continued right to the ends of the rail, as it is often found that the work is done less carefully at the ends, with the result that they have a somewhat different curve from that of the body of the rail. Where a roller rail-bending machine is used, some roads pass all rails through this, to bend the rails for curves and to take out any kinks in rails for tangents. If no bending machine is available, the rail may be curved by resting the ends on ties laid across the track, then placing a hook or curving hook under the track rail at a point opposite the middle of the rail to be bent. One end of a wooden lever or track lever is held by the hook, the lever resting on the rail and being pulled down by men holding its free end. Slight kinks in curved rails in the track may be detected by testing the curve with a cord (as described under "Lining" and "Curve Work"), and then taken out by extra spiking. In curving the rails the middle ordinate of a 30-ft. rail will be almost exactly ¼-in. for each degree of curve. The side or quarter ordinates are always three-fourths of the middle ordinate. Table No. 23 gives a list of middle ordinates for different lengths of rails and different degrees of curvature, calculated to the nearest 1-16-in., but many roads use tables varying only by ⅛-in. The middle ordinate (M) of a 30-ft. rail, the quarter ordinates (R) of a 30-ft. rail, and the middle

ordinate (S) of a rail of any other length (T) may be obtained by the following formulas:

$$M = 0.02 \times \text{Degree of Curve.} \qquad R = M \times 0.75. \qquad S = M \times \left[\frac{T}{30}\right]^2.$$

TABLE NO. 23.—MIDDLE ORDINATES FOR CURVING RAILS.

Degree of Curve.	Length of rails (feet). 10.	12.	14.	16.	18.	20.	22.	24.	26.	28.	30.	33.
	Middle ordinates (inches).											
½	..	..	..	..	..	..	..	..	..	..	⅛	⅛
1	..	..	..	..	..	..	..	⅛	⅛	⅛	¼	¼
1½	..	..	..	..	⅛	⅛	⅛	⅛	¼	¼	⅜	⅜
2	..	..	⅛	⅛	⅛	⅛	¼	¼	⅜	⅜	⅜	⅝
2½	..	..	⅛	⅛	¼	¼	¼	⅜	⅜	½	½	¾
3	..	⅛	⅛	⅛	¼	¼	⅜	½	½	⅝	⅝	⅞
3½	..	⅛	⅛	¼	¼	⅜	⅜	½	⅝	¾	⅞	1
4	⅛	⅛	⅛	¼	⅜	⅜	½	⅝	¾	⅞	1	1⅛
4½	⅛	⅛	¼	¼	⅜	½	½	⅝	¾	⅞	1	1¼
5	⅛	⅛	¼	⅜	⅜	½	⅝	¾	⅞	1	1⅛	1⅜
5½	⅛	¼	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅝
6	⅛	¼	⅜	⅜	½	⅝	¾	⅞	1⅛	1¼	1⅜	1¾
6½	⅛	¼	⅜	½	½	¾	⅞	1	1⅛	1⅜	1½	1⅞
7	⅛	¼	⅜	½	⅝	¾	⅞	1	1¼	1½	1⅝	2
7½	⅛	¼	⅜	½	⅝	¾	1	1⅛	1⅜	1½	1¾	2⅛
8	¼	¼	⅜	½	¾	⅞	1	1¼	1⅜	1⅝	1⅞	2¼
8½	¼	⅜	⅜	⅝	¾	⅞	1⅛	1¼	1½	1¾	2	2⅜
9	¼	⅜	½	⅝	¾	⅞	1⅛	1⅜	1⅝	1⅞	2⅛	2½
9½	¼	⅜	½	⅝	¾	1	1¼	1⅜	1¾	2	2¼	2¾
10	¼	⅜	½	⅝	⅞	1	1¼	1½	1¾	2	2⅜	2⅞
10½	¼	⅜	⅝	¾	⅞	1⅛	1⅜	1⅝	1⅞	2⅛	2½	3
11	¼	⅜	⅝	¾	1	1⅛	1⅜	1⅝	2	2¼	2⅝	3⅛
11½	⅜	½	⅝	¾	1	1¼	1½	1¾	2⅛	2⅜	2¾	3¼
12	⅜	½	⅝	¾	1	1¼	1½	1⅞	2⅛	2½	2⅞	3⅜
12½	⅜	½	⅝	⅞	1⅛	1⅜	1⅝	2	2¼	2⅝	3	3⅝
13	⅜	½	⅝	⅞	1⅛	1⅜	1⅝	2	2¼	2⅝	3	3¾
13½	⅜	½	¾	1	1¼	1½	1¾	2⅛	2⅜	2¾	3⅛	3⅞
14	⅜	½	¾	1	1¼	1½	1¾	2⅛	2½	2⅞	3¼	4
14½	⅜	⅝	¾	1	1¼	1⅝	1⅞	2¼	2⅝	3	3⅜	4⅛
15	⅜	⅝	¾	1	1¼	1⅝	1⅞	2¼	2⅝	3⅛	3½	4¼
15½	⅜	⅝	⅞	1⅛	1⅜	1⅝	2	2⅜	2⅞	3¼	3⅝	4⅜
16	⅜	⅝	⅞	1⅛	1⅜	1⅝	2	2⅜	2⅞	3¼	3¾	4⅝

30-ft. rail: 17°, 4 ins.; 18°, 4¼ ins.; 19°, 4½ ins.; 20°, 4 9/16 ins.

Cutting Rails.

Where much cutting is to be done, as in fitting switch and frog work, etc., a portable track saw should be used. When a rail must be cut on the track, the most common practice is to nick it all round with a cold chisel and then to lift up the end of the rail and drop the rail so that the nicked part will strike upon the cutting block, a tie, or a piece of rail. This is usually effective, but it is a barbarous and improper way to treat steel rails, and is more or less dangerous to the men, besides having a decided tendency to put a kink in the rail. A better plan is to mark all round the place to be cut with a chisel, then lay the rail along the ties, holding one end down with a tie and putting the cutting block underneath, 4 or 5 ft. back from the cut. A bar is then placed across the rail at a point ahead of the cut, one of the track rails being used as a fulcrum and one man bearing hard down upon the bar. Another man then holds the chisel in the cut at the bottom of the web (or lower fillet), while a third man strikes the chisel a sharp blow with a hammer or sledge. If the rail does not promptly break, the chisel may be held on the other side of the rail for a second blow. The rail should be carefully measured for the exact position of the chisel cut, and the cut should be made neatly and cleanly at the required

place. A rail bender may be used to break the rail by bending it at the chisel cut, and in any case the rail should be straightened after being cut, as it is likely to be kinked in the operation. The edges of the head should also be filed if necessary.

Spiking.

All main tracks should have at least four spikes in every tie, the two outer spikes being nearer the edge of the tie (on double track this should be the side first struck by the train), and the two inner spikes near the other edge, but none of the spikes being less than 2 ins. from the edge of the tie. This arrangement is designed to hold the tie square with the track and prevent slewing, but is a practical detail not infrequently neglected, the spikes being too often placed in line across the tie. Double spiking is sometimes required on curves where rail braces or tie-plates are not available; the extra spikes being required on the outside to resist the lateral thrust from the wheels. Spikes should not be driven until the ties are in position, properly spaced, and square across the track. If this is not

A Good Spiker.

A Bad Spiker.

Fig. 206.—Spiking.

attended to, the spikes will not hold the rail properly when shifted to proper position. The tie should be held up by bars while the spikes are being driven, but should not be lifted from its bed. Too often, however, one or two men hold up the tie so as to raise it while the spike is driven, so that the tie then hangs from the rail by the spike.

The spiking should be done carefully, each spike being set vertically and driven straight down, with its shank touching the edge of the rail base. The spiker should bring the maul down with a long swinging stroke, striking squarely on the head of the spike, and keeping his hands well down, so that the handle of the maul will be approximately horizontal, as shown in Fig. 206. He should in no case set the spike sloping from or towards him, as it reduces the hold of the spike head on the rail, while the head may very likely be broken by the last blow of the maul, and the spike will be bent by being pulled out. The spike should not be set a little distance from the rail and then struck on the back to drive it

sideways into position, as this will enlarge the hole in the tie, weakening the hold on the spike and forming an entrance for water and moisture to rot the interior of the tie. Neither should it be driven slanting to or from the rail, for the purpose of tightening or widening the gage, but the rail should be thrown to line with a bar and then properly spiked. The last blow on the spike should be struck lightly, so as to avoid breaking the head of the spike when it comes to a bearing on the rail. At joints, the spikes should be driven in the slots of the angle bars, except on bridges, where free play is usually allowed for any creeping of the track, so as to avoid strains on the structure or its floor system. In warm weather, the spike should be driven against that side of the slot furthest from the end of the rail, thus allowing for contraction of the rail in colder weather.

In pulling spikes, care should be taken not to bend or break them, loosening tight spikes by giving them a tap on the head before applying the claw-bar. When old spikes are drawn, the holes should be filled with wooden plugs (those cut by machine being preferable); tar or sand may also be used. The new spikes may also be dipped in creosote oil, tar or resin before being driven, but it is doubtful if this has much effect in preserving the tie from decay at the spike holes. Long boat spikes should be used where thick shims are placed between the rail and the tie, and used also for fastening road crossing planks to the ties. The section men and trackwalkers keep continual watch of the spikes, but the Erie Ry. has a good plan of sending two men over each section, twice a year, to drive down every spike; they also replace all spikes which are broken, are not snug against the edge of the rail, or are not in proper position in the slots of the angle-bars.

Bolting.

Rail joints should have the bolts screwed up tight as soon as put on, with nutlocks or washers in place, but the bolts will usually have to be gone over again and tightened up with a wrench in a few weeks. The men should never put long handles on the wrenches in order to increase the leverage, as this will result in stretching or stripping the threads of the bolt or nut, so that the tightness and security of the joint will be impaired, even if the bolts are not made entirely useless. A strong, firm pull on an ordinary wrench is all that is required. The nuts should be slackened and re-tightened in the spring (before warm weather), and in the autumn (before cold weather), so as to insure proper freedom for the expansion and contraction of the rails. If held too tight, the rails may shear the bolts or buckle the track. All broken or damaged bolts should be at once replaced, and each joint kept fully bolted and fitted with the proper nuts, washers or nutlocks. In removing bolts, while too much time should not be lost in trying to get off a rusty nut, care should be taken to see that the men do not get in the habit of saving time and trouble at the expense of damaging good bolts by knocking off the nuts and ends of bolts with a hammer, thus rendering both nut and bolt only good for scrap. If the bolts are comparatively new, the nuts may be loosened by tapping and the use of oil; and when the nut has been taken off and the bolt removed, the nut should be screwed on the bolt to prevent loss, and the nut and bolt thrown into a box or keg, and not left lying in the ballast.

Shimming.

When the ballast is frozen it cannot be tamped, and if the track is heaved by frost, the surface is made uneven both transversely and longitudinally. This must be tested by a level for the former and by sighting or the use of a long straight-edge for the latter. Wooden plates or shims must then be placed between the rail and the tie, to bring the rail up to proper surface. The upper face of the tie should not be adzed to lower the rail, unless this is absolutely necessary, but the shims should be placed on the lower ties. Shimming is also required with ballast which is so soft after heavy rains that tamping is impracticable, the ballast and roadbed being so saturated that no other method of surfacing is effective. In some very bad cases, or in accidents, blocking must be used under the ties, but this should be avoided when possible and the foreman must see that this blocking is not forgotten and left in place, but that it is taken out when the shims are removed, or when the ballast has dried out sufficiently to give the track a proper bearing. As the frost comes out of the ground and the ground settles, thinner shims must be substituted for the thicker ones, to prevent surface bending of the rails. The shims should never be left in place after the spring, and as fast as they are removed the spike holes in the ties should be properly plugged. Heaving is most troublesome in earth and clay, but is also felt in gravel. Where much trouble is experienced from heaving, it will usually be found economical to apply gravel ballast liberally, as the spiking and shimming injure the ties and spoil the permanent surface of the track.

The shims may be cut by the sectionmen, but it is better to use those cut by machinery, having two spike holes bored diagonally opposite one another. They are about 6 ins. wide, and the length should be at least equal to three times the width of the rail base, so as to give ample room for spiking and keeping the spikes clear of the angle-bars. The thickness is from ¾-in. to 2 ins. If a raise of more than 2 ins. is required, a piece of 1-in. to 3-in. plank should first be spiked to the tie by boat spikes, the plank being about 2 ft. long, or as long as the tie if both rails have to be shimmed. Upon this plank should be placed shims to bring the rail to the required level, these being fastened by long spikes passing through shims and plank into the tie. With specially high shimming it is well to place rail braces outside the rails, especially on curves. Where tie-plates are used, the plates should not be taken off, but the shims placed on them, and if the shimming is high, a tie-plate may be placed on its top. The tie should be adzed to give a level seat for the shims. Spiking should be attended to as fast as the shimming is put in, and if a whole rail length is to be shimmed, the joint, center and quarter ties should first be shimmed and spiked.

Fencing.

In setting fences, the distance from the center line of the track may be measured by a tape, and the line of fence set off by a cord or chain 100 to 200 ft. long, having tags at the post spacing. When this is stretched a small hole is cut at each tag as a guide to the post setters. The post holes should be of uniform depth, gaged by a stick. The height of the post above ground may be gaged by a stick having a flat piece nailed on the bottom, and hav-

ing also notches to hold the fence wires at the proper spacing while being stapled to the posts. On curves, the position of each post should be measured from the center of the track, and a mark made or stake driven. For wire fencing, posts may be set and temporarily braced at intervals of 40 to 80 rods (660 to 1,320 ft), and one wire stretched first as a guide for the other posts. On the inner side of a curve, the wires should be put on the track side of the post, or on the track and field sides of alternate posts. The wires are attached to a straining post and set up by a stretcher, but in the absence of this tool a lining bar may be used, placed diagonally, with the top inclined towards the anchor post, and the wire being looped around the bar. In summer the wires must not be drawn too tight. With board fences, the alternate posts may be set 16 ft. apart, and a line of boards nailed along them will serve as a guide for lining the intermediate posts. The boards should be on the farm side of the posts. The materials and labor per mile for a four-board fence with posts 8 ft. apart, and a five-wire fence with posts 16 ft. apart, are about as follows:

Board Fence:
- 660 posts.
- 1,320 board, 1x6 ins., 16 ft. long, 10,560 ft. B. M.
- 660 battens, 1x6 ins., 4 ft. long, 1,320 ft. B. M.
- 250 lbs. nails.
- 65 days' labor for one man.

Wire Fence:
- 330 posts.
- 26,400 ft. of wire at 440 lbs. per strand, 2,200 lbs.
- 75 lbs. staples.
- 27 days' labor for one man.

The average labor on a six-board fence, including setting posts, is 8 to 10 panels per man per day where the boards meet on the post, or 13 to 15 panels where they lap on opposite sides of the post. On a four-wire fence, with 16-ft. panels, the average is about 15 panels. These figures vary, of course, with the details of the work and character of the men. The cost per 100 rods (1,650 ft.) for fence building and repairs, with labor at $1.50 per day, has been estimated as follows: Five-wire fence: $6 for removing old fence and posts; $16.50 for putting in new posts 3 ft. to 3 ft. 6 ins. deep, and stringing wires. Board fence: $4.50 to $5 for removing old fence and posts; $32 for putting in new posts 8 ft. long (set 3 ft. deep) and putting on seven boards; or $42 for posts 10 ft. long (set 3 ft. 6 ins. deep), and putting on nine boards. The painting or daubing of advertisements on board fences is very objectionable, and at least one road has forbidden it, making a practice of painting out such disfiguring marks.

Clearing Right of Way.

All grass, weeds and brush on the right of way should be cut at least once a year, and preferably twice a year. This should be done in the months which are most suitable, according to the latitude, but being in any case done before the seeding time of the plants. After the grubbing, cutting and mowing, the material should be raked into heaps and burned as soon as it is dry enough, care being taken that the fire is not allowed to extend to fences, trestles or adjoining land. Old ties, splice bars, tools, etc., found during this clearing up should be removed and properly disposed of. If the brush on the right of way is allowed to grow too long, it is liable to cause accidents by concealing cattle, which may stray on the track in front of a train, while it is also liable to catch fire in dry weather,

such a fire being hard to check or stop. Reports of locomotives which throw sparks badly, and of fires started by sparks from locomotives, should be made by the section foreman and roadmaster. The spark arresters of locomotives should be examined frequently in hot, dry weather, when standing crops, weeds on the right of way, etc., are liable to catch fire. Where the right of way is covered with good grass, it may be mowed and used or sold for hay under the direction of the roadmaster.

The grass and weeds in the ballast and along the sides of the roadbed have also to be cut or pulled up, and this is tiresome and unpleasant work, though necessary for keeping a good looking track. A long handled sharp hoe is better than a shovel if there is much of this work to be done. Where this work is only done periodically on lines not kept in the best condition for appearance it may be economically done by machinery, as noted under the head of "Ditching Machines" in Chapter 18.

The Sheffield weed-cutting hand-car has two toothed cutter bars (like those of a reaping machine) projecting from a frame between the wheels. The position is regulated by levers, and the knives will cut close to the ground and to a distance of 8 ft. from the rail. They fold together and swing up to a vertical position at the side of the car when passing an obstruction. It will work on level ground or on slopes, and when the weeds are not harsh it may be run by 4 or 6 men at a speed of 5 miles an hour. In some few cases, with earth ballast, it is considered well to let the grass grow, merely cutting it down so low that it will not get on the rails. Where the weeding is done by hand, it should be extended to a "grass line," 5 or 6 ft. from the rail, this line being set out by a cord and stakes, or marked by a cutter attached to a hand-car. A timber may be bolted across the car, having hinged to its projecting end a bar parallel with the track and carrying a cutter and plow handle.

Various methods have been tried for killing the grass and weeds growing in the ballast, but though such methods would be advantageous in saving time and labor, none of them have yet so combined efficiency and low cost of operating as to be really practicable for general work. Such a method would be specially advantageous for roads having many weeds and few section men, which is the condition of many roads in the south and west. Brine, gasoline or oil burners, steam jets and electricity are among the means experimented with in this direction. In experiments with electricity on the Illinois Central Ry., a "brush," 10 ft. long and 4 ins. wide, was made of fine bare copper wires and suspended from the front of a flat car, so that it would almost touch the ground. Another car contained an engine, dynamo, transformers, etc., steam being taken from the locomotive. The cars were run at a speed of about 5 miles per hour, and two trips would be found sufficient to absolutely kill all vegetation. The brush was in short insulated sections, so that all the current would not be discharged through any one weed, etc., forming a more than usually good conductor. A current of 10,000 volts was found to be most satisfactory. For general work, however, the cost of this method would be prohibitive. A strong solution of brine, delivered from a sprinkling attachment on a water tank car, has been tried. It effectually killed the weeds, but caused a slime on the rails which led to slipping of the engine wheels and corrosion of the rail, and it was therefore abandoned.

Burning weeds with jets from burners using crude oil sprayed by steam or compressed air has been worked with success on several railways. On the Chicago Great Western Ry., with oil at $1\frac{3}{4}$ cts. per gallon, the cost for fuel and wages (3 men) was $1.07 per mile. The car is propelled at a speed of one to three miles an hour, according to the thickness of the weeds. The Atchison, Topeka & Santa Fe Ry. uses a steel flat car 50 ft. long, with side aprons over and beside the rails to protect the flame from wind. A shield at the front end of the car covers the burners and is about 3 ins. above the rails, with side aprons touching the ground. This is raised at bridges, crossings, etc. Two brake pumps force the oil into a tank under a pressure of 70 lbs. A light crude oil is used, with a consumption of about 8 gallons per burner per mile. There are four burners and the shield spreads the flame to a width of about 10 ft. and a length of 15 ft. Steam jets from the locomotive, or a gang of men following, extinguish any ties set on fire. The speed is 4 miles per hour early in the season or 3 miles with thick coarse weeds. The cost of operation is $50 per day and 20 to 30 miles can be covered, making $2.50 to $1.66 per mile.

Policing.

This work includes the general maintenance of the roadway in neat and proper condition, and is to be attended to continually. Weeds must be kept cut, and trimmed to the grass line; ballast properly dressed and sloped; ditches cleaned; rubbish picked up, and spare material properly placed. Combustible material must be kept cleared from around bridges, trestles, signal posts, etc.; dirt and gravel must be removed from bridge seats and trestle caps, and care taken to prevent ballast from working over onto the bridge abutments or falling into streets below. Large loose stones may be neatly piled around the bases of signal posts, sign posts, etc., to keep vegetation from growing. All trees that are in danger of falling on the track, or that interfere with the passage of trains or obscure the view, must be removed or trimmed. If they are on private land, and the owner objects to such work, a report must be made as to the circumstances.

All old track material, material from cars, old ties, rubbish, etc., must be picked up and removed from the track, all scrap being carried to the section tool house to be sorted and properly disposed of. All scrap iron, lumber, etc., must be neatly piled on platforms. New material, such as rails, ties, etc., must be properly piled or stacked, and no material should be thus piled within 8 ft. of the track. Care should be taken to have a neat and tidy appearance of the section, with track full spiked and bolted, switches clean and well oiled, cattle-guards and road crossings in good condition, fences in repair and wing fences at cattleguards kept whitewashed, ballast evenly and uniformly sloped and free from weeds, and sod line cleanly cut (usually 7 to 10 ft. from center of track or 12 ins. from ends of ties). Sidetracks in yards should also be kept free from weeds and rubbish, old paper, scrap, etc. Station grounds also must be kept neat. Signs must be upright and in good repair. Section houses must be clean and tidy, with tools, track material, scrap, etc., properly sorted and placed. When such a system is first introduced, the foremen will probably complain that they

cannot do their work properly and spare time to keep the road looking neat, but experience has shown that it is very easy to do both if the men work systematically. It is much easier to keep the line and yards neat than to have a periodical cleaning up at long intervals.

Every possible means consistent with general attention to track work, should be taken to keep people from walking on or at the side of the track, and from using the railway as a public path. This is specially necessary near cities, where the traffic is heavy. In such cases, where people habitually walk on the track, a liberal covering of coarse broken stone or slag, or even cinders may be laid upon the ballast between the rails and tracks and upon the berme at the edge of the roadway. This will soon drive off those persons who cannot comfortably walk on the ties. This matter is far too often neglected, and railways are themselves partly responsible in not checking the habit which the public has acquired of treating the track as a public way.

Station Grounds and Buildings.

In order to have a good reputation for the road on the part of the public, it is very desirable that the grounds at stations should be kept clean and tidy and free from rubbish. On some roads this work is delegated to the station agent, who has his men attend to it, while on other roads it is part of the section gang's work. The latter is the better plan if the force is sufficient, and if the work is done by direction of the roadmaster, the station agent not being given authority to employ the section men for this purpose when he thinks proper. On roads having stations with lawns, flower beds and nice grounds, a special force is sometimes kept to attend to them. Many roads now employ landscape gardeners, and the Boston & Albany Ry. has on each of its principal divisions a gardener with 5 to 12 men, who grade, plant and seed the grounds, and take care of them. These men cut the grass with lawn mowers, and do the weeding, trimming of shrubbery, etc. They also attend to places where the banks are graded and seeded. This force is included in the roadway department. The Pennsylvania Ry. also employs landscape engineers and a large force of gardeners and spends large sums of money in making and maintaining attractive grounds. Such roads have a reputation for the appearance of the stations. The Chicago & Northwestern Ry. has on its principal division a florist, with enough assistants to take care of the flowers, etc. A greenhouse is provided. The station agents attend to watering the lawns, etc., and the roadmasters detail a man once a week to cut the grass. In addition to this, the slopes are being sodded, thus improving their appearance and tending to prevent sliding and washing. All sodding, cinder edging, trimming of toe of ballast slopes, etc., should be done to a line. On the Michigan Central Ry., greenhouses and 10 acres of land for gardening are provided at Niles for the maintenance of station grounds on a division of 170 miles. Many roads have adopted the policy of making "parks" at stations, sodding the ground and planting trees. It is specially important to have attractive grounds and pleasant surroundings at important stations and at junctions, where passengers may have to change trains or to stop over for connecting trains. Virginia creeper or Boston ivy make good creeping plants. Shrubbery is generally preferable to flowers, as the latter

last so short a time, and the beds look dismal when they are bare. The arrangement should not be too formal in design.

In all ordinary cases, however, much may be done by foremen and station agents. The agent especially should see that the grounds and platforms are kept free from old papers and other rubbish. A plot of turf, cinder or gravel pathways, a flowerbed, a creeper on the building or on a pile of rockwork, can be had with little trouble, and have a great effect upon the general appearance of a station. The approaches and surroundings on the town side of the station should be cared for as well as the grounds on the railway side. The platforms should be convenient and in good repair and the fences kept in repair. Much may be done in maintaining a good appearance along the road by fitting up a car for painting by compressed air, as noted under "Buildings."

The yards, spaces between tracks, etc., at stations should be neatly leveled and covered with ashes or gravel, and should be kept in order by the section men, but strict rules should be made and enforced against the scattering of ashes and cinders from engines (which should be dumped at specified points), and the sweeping of rubbish and dirt from the station or cars upon the track. Every station should have a can or bin for waste paper and rubbish, which should be emptied at intervals into a dirt car; similar receptacles should be provided at yards or places where cars are cleaned. At large terminal yards one man may be kept busy clearing up paper and rubbish. It is a good plan to have station inspectors to see that the stations, waiting rooms, closets, section boarding houses, etc., are kept in proper and sanitary condition, and that the grounds are properly cared for. Cleanliness should be enforced in every case, but the standard of appearance will, of course, vary according to the financial condition of the road and the size of the force.

Old Material.

In all renewals, and the periodical policing of track, cleaning up of yards, etc., it must be borne in mind that new material must be properly used and cared for, and not wasted, and also that no old material should be simply thrown away as useless. Even if really useless for railway purposes, the material has a certain selling value, which is wrongfully lost to the company if the material is thrown away. These remarks apply also to the wreckage and scrap resulting from train accidents and the burning of cars. Record must be kept of the disposal of all scrap and old material.

Old rails should not be left hidden in the grass and weeds of the right of way, but properly piled for shipment, as they may be used for sidetracks or branches, sold for scrap, or even made into " new rails" of somewhat lighter section by heating and rerolling. Old rails may be sorted into three classes: (1) Rails suitable for relaying in main line, which are usually only the best rails from tangents; (2) Rails suitable for sidetracks; (3) Scrap rails, or any which will not give 20 ft. suitable for sidetrack. Old ties have rarely much value, but if thrown away, sold, burnt, used for cribbing, etc., all unbroken spikes should first be pulled, and when ties are burned the ashes should be raked over for spikes. In piling old rails, the splice bars and bolts should all be removed, good splice bars sorted in pairs and broken bars kept separate. Nuts and bolts, if good, should be kept to-

gether, but broken bolts should have the nuts removed and kept separate. Many spikes thrown away or put aside as scrap might be used over again if properly driven in the first place and properly drawn. Foremen should be careful to see that all track and car material, etc., is picked up regularly, and that their men do not get in the habit of flinging old bolts, spikes, etc., down the bank. In removing bolts, the nuts should be unscrewed properly, the bolt taken out, and the lock and nut put back on the bolt. If, however, the nut is so rusted or wedged on the bolt that it will not unscrew, it is more economical to knock off the nut with the end of the bolt in it, with a sledge, than to waste time in forcing the wrench. Only good discipline and good management of men can insure the exercise of proper judgment as to when to knock off nuts in this way. Care should be taken not to hit the head of the rail.

At the section tool house, the scrap should be piled and sorted (as described under "Policing"), nuts taken off broken bolts, etc., this work being done in wet or stormy weather, or when the men cannot work on the track. All large iron, lumber, etc., must be neatly piled on platforms; car scrap, links, drawbars, couplers, etc., being kept separate. Small scrap, such as bolts, nuts and spikes, may be kept in shallow boxes or in old spike and bolt kegs. Rails may be piled on the right of way at mile posts. Old ties may be stacked on the right of way, until permission is given to burn them, the ties removed being piled at the end of each day's work and not left in the ditch or on the roadbed.

Under this heading it is appropriate to refer to the treatment and disposal of the material found in the general scrap pile at division points or main shops. The style of material delivered for the scrap pile is significant of the character of the men sending it, as for instance one man who is somewhat careless and finds it easier to use new material than to sort out the serviceable from the unserviceable scrap at his tool house, will send in many old bolts and nuts that are good for further use. In some cases it may be advisable to go to the expense of putting in a set of small rolls to bring odd sizes of iron to standard sizes for bolts, plates, etc.; a shear (perhaps operated by an air brake cylinder with 4-ft. lever and 6-in. jaw) for cutting rods, or even to build a small furnace for heating angles, etc., to be rerolled. Of course it must be borne in mind that while with a single large scrap pile at one large central shop it may be economical to carefully sort and handle the material, and treat it as above noted, this may not be the case with smaller piles at division shops. In some cases, also, an article made from scrap may be more expensive than a newly purchased article. These are matters for the exercise of judgment and calculation in order to insure real economy.

In most scrap piles there is a great proportion of bolts. These may be sorted as to their diameters and length and stored in compartments. Stub ends of ¾-in. to 1-in. bolts, about 5½ ins. long, may be used for making track bolts, a bolt heading machine at the shops being equipped with suitable dies. Nuts may be cleaned of rust by pickling in a weak solution of hydrochloric acid, and then used again, or if damaged they may be slightly compressed by dies in a bolt heading machine and then retapped. Plates and shapes may be utilized for small plate girders to cross culverts, etc. Lining bars, clawbars, wrenches, etc., may be success-

fully made from scrap steel tires, and the slide plates for switches may be made from elliptic springs, the plate being heated to a cherry red and then put in a bulldozer, where it is sheared off and has two square holes punched in one operation. Old flues, which bring little as scrap, make good fencing for station grounds, posts for track signs, or grates for cinder pits where fireboxes are cleaned out. Old fish plates or plain splice bars may be sheared to length and stamped to shape for rail braces. In sorting, care should be taken to pick out any new or practically uninjured material which may by accident or carelessness have got in with the scrap. When sorted, the stuff should be arranged so as to be easily seen and got at, but discrimination should be exercised so as not to store a lot of miscellaneous material on the chance of its being of some possible use eventually.

CHAPTER 20.—GAGE, GRADES AND CURVES.

Gage.

The gage of the track is the transverse distance between the inner sides of the rail heads, and if these sides are sloping the measurement is usually taken at about half the depth of the head. The standard gage of 4 ft. 8½ ins. is now practically universal, but it is much to be regretted that a few roads are still using a gage of 4 ft. 9 ins., as wheels which are fitted for the best running on standard gage have undue side play for the wider gage, which is hard upon the track, especially at frogs and switches, and adds materially to the cost of maintenance. There is, however, a tendency toward the elimination of this abnormal gage. There is practically no gage wider than the standard now remaining in this country, and the proportion of narrow gage is so small as to need little special mention in this work. Reference may, however, be made to interesting articles upon the work of changing gage, published in "Engineering News," New York, Aug. 25, 1892, and Sept. 13, 1894, and in the "Journal of the Association of Engineering Societies," October, 1884.

Change of Gage.

Small lines of narrow gage are being widened gradually as they become absorbed by standard gage railways, and it may be useful here to describe the method followed on the Louisville & Nashville Ry. in widening the 3 ft. gage of a mineral branch 62 miles long. The subgrade was widened and the trestles were strengthened, and then standard gage ties replaced every third narrow gage tie on tangents, every other tie on curves up to 6°, and all ties on curves sharper than 6°. The outer spikes for the standard gage were driven, and seats were adzed for the rails. To set the spikes, a track gage or spike setter of ½ x 2-in. iron was used. The ends of this were curved down beyond the rails, so that when set on the 3-ft. gage track, the ends rested on the tie, the ends being flattened out to 1½ ins. wide and 1 in. thick for a width of 1½ ins., this representing the rail base. A loose piece, ⅝-in. wide, attached to each end of the gage by a wire, provided for the widening of gage on curves. The "spotters" for adzing the ties were

wooden bars, 3 x 3 ins. (rounded at the middle), with blocks nailed on the under side as gage lugs for the 3-ft. track, while under each end a strap of ⅛ x 1¼-in. iron was bent to form a rectangular loop, 5 ins. wide over all, and deep enough to touch the tie when the bar rested on the rails. The work of changing the rails was done by the force then on the line. The one train per day was stopped, but the entire work only occupied four days. The force consisted of 180 men, exclusive of foremen, and these were organized into six gangs of 30 men each, while each gang was assigned to a division of about eleven miles, including sidings. The length of the divisions depended upon the amount of curvature to be encountered. Each gang was in general charge of a foreman, and had another foreman to look after the spiking. Work was commenced at a given point and continued until finished, the time being from two to three days. The organization of each gang was as follows: 8 men drawing spikes, 4 men throwing rails, 12 men spiking, 1 man distributing spikes, 2 men pushing hand cars, 1 man carrying water, 1 man driving down spike stubs, 1 extra man. The equipment for each gang was as follows: 9 clawbars, 4 lining bars, 3 gages, 13 spike mauls, 1 water barrel, 2 water buckets, 1 standard gage dump car, 1 narrow gage dump car, 1 standard gage hand car, 1 narrow gage hand car, 1 punch, 4 cleavers, 1 wrench, 2 rails 18 or 20 ft. long, and 1 pair of splice bars and bolts, to be placed about the middle of every curve of over 6°, in case rails were to be cut.

In widening the 3 ft. gage of the Columbia & Western line of the Canadian Pacific Ry. in 1899, the track was entirely rebuilt during the day, traffic trains being run only at night. A 28-lb. third rail was laid for these narrow gage trains and connected up at the end of each day's work. Material was carried ahead on narrow gage work trains. The whole track was renewed out of face, thus allowing joint ties to be properly placed and rails to be full spiked. By this method, a gang of 40 men could remove and rebuild 2,500 ft. of track per day, the maximum being 3,800 ft. Rails were cut for standard gage switches, temporary narrow gage switches being laid as the work progressed. The 30° curves were laid 1-in. wide in gage, with an elevation of only 1 in.

Grades.

The maintenance work on grades may be increased very considerably if the traffic is heavy, owing to the increase in wear of rails resulting from the use of sand in ascending and the application of the brakes in descending, and also to the general displacement and disturbance of the track, and the creeping of rails, all of which are aggravated on steep grades. For these reasons, as well as the increased cost in operating train service, it is economy to keep the grades down as much as possible in construction, especially if there is a heavy traffic probable. On the Erie Ry. great expense was incurred in order to keep the grades down to 1.14%, and many railways have either spent large sums in reducing grades or are operating at more or less disadvantage from heavy grades. On the other hand, for light traffic or temporary use, heavy grades may wisely be used to avoid the immediate construction of heavy permanent works, as in the case of surface lines in mountain districts to avoid tunnels on a low grade line, which may be built later. Some particulars of the grades used in switch-

backs on main lines will be found in the chapter on "Permanent Improvements." In addition to maintaining good track on the grades, care must be taken to maintain the grades at the uniform prescribed rate. Surfacing, etc., may eventually result in breaking up the grade line in such a way as to materially increase the actual grade in some places. For this reason, the engineer or roadmaster should occasionally run a line of levels over the division, especially on heavy grades, as any such change in the grade line may have a serious effect in reducing the hauling capacity of the locomotives.

Compensation of Grades.—When curves occur on heavy grades the grade should be so reduced that the combined train resistance due to grade and curve will not exceed that due to the maximum grade allowed on the tangent. This reduction is variously taken at 0.1 to 0.05% per station per degree, 0.04% being about sufficient on all curves. Thus with a maximum grade of 2% on tangents, and a rate of compensation of 0.04% per degree, the maximum grade on a curve of 6° would be 1.76%. At or near stations and stopping places the rate of conpensation should be nearly twice as great, or 0.06 to 0.08%. On the Denver & Rio Grande Ry. it is 0.03%, while on the Illinois Central Ry. the minimum is 0.04%. The reduced curve usually extends beyond the curve. The amount of elevation lost by compensating the grade is found by multiplying the degree of central angle of the curve by the rate of compensation, and this elevation divided by the length of grade will give the rate by which the tangent maximum must be increased to introduce the compensation without a final loss in elevation. The change in grade may commence at the nearest even station, and not necessarily at the P. C. or P. T.

On the Northern Pacific Ry., a compensation of 0.03% has been found insufficient; 0.04% gives fairly good results, though with curvature frequently changing in direction, it is not quite sufficient for full compensation, while on very long curves in one direction, the rate is somewhat in excess of requirements. This, of course, is only noticeable on long trains, and the condition of the cars has a good deal of influence upon it. Mr. C. S. Bihler, Division Engineer of the N. P. Ry., states that it appears that there is a certain resistance on entering and leaving a curve, which is independent of its length, but of course bears some relation to the degree of curve, and that curve compensation might be determined according to the formula given below, in which (D) designates the degree of curve, (N) the length of the curve in stations of 100 ft., and (A) and (B) are constants, the value of which would be about 0.1 for (A) and 0.03 for (B).

$$\frac{D \times A}{N} + D\,B.$$

Virtual Grades.—Great assistance to trains in surmounting heavy grades may be derived by utilizing the momentum stored in the trains at high speeds, the virtual grade being thus easier than the actual grade. While this is almost universally recognized, a virtual profile has been rarely adopted. In connection with the proposed reduction of grades on the Ontario & Quebec Division of the Canadian Pacific Ry., in 1900, the value of this momentum was carefully considered. The original line between Montreal and Toronto has maximum grades of 1% in both directions, which, being uncompensated for curvature, are equivalent to about 1.12%. The gross

westbound tonnage, including locomotives, is about 62% of the eastbound; and it is proposed to balance the grades to conform to the tonnage by reducing the eastbound to 0.6% compensated, without any reduction in the westbound grades. With such grades, the locomotive rating behind tender will be 1,600 tons east and 900 tons west. The latter will usually be somewhat reduced, being composed largely of empty cars, which present a greater resistance per ton to moving the loaded cars. The matter has been discussed in Wellington's "Economic Theory of Railway Location" and (with reference to the Canadian Pacific Ry.) in Engineering News, Vol. 44, 1900.

Vertical Curves on Grades.

The angle formed by the junction of grade lines exceeding 0.5% may be rounded off by vertical parabolic curves. The advantages of these in relation to the operation of train service is discussed in Wellington's "Economic Theory of Railway Location," and it is pointed out that they are of greater importance at sags than at summits. The length recommended is 200 ft. on each side of the vertex, but in present practice it varies from 300 to 800 feet in all. On the Northern Pacific Ry., the parabolic curves are not less than 50 ft. long for each change of 0.1% in rate of grade on summits, and 0.05% in sags. This makes the curves 200 ft. long in sags for each change of 0.1% in grade. The method of laying out these curves is given in Searles' "Field Engineering." Table No. 24, giving corrections for grade elevations in laying out such curves, was prepared by Prof. Nagle ("Engineering News," New

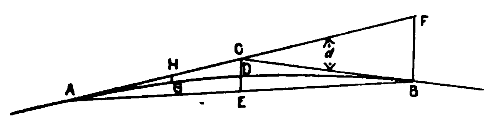


Fig. 207.—Vertical Curves for Grade Intersections.

York, Nov. 26, 1896), and gives the vertical distance from grade line to curve at different points along the curve. The length of curve should be about 600 ft. at summits, and 800 to 1,200 ft. at sags. The curve chosen is a parabola, because of the ease with which any correction may be found when the correction at the vertex, or meeting point of grade lines, is known. Two properties of the parabola are utilized: (1) that ordinates from tangent to curve vary as the square of the distance from the point of tangency; and (2) that the curve bisects the vertical intercepted between the vertex and long chord joining the P. C. and P. T. In Fig. 207, H G (= T) is the correction at distance X from A; C D (= M) is the correction at the vertex, and 2 L is the length of the curve in stations; then the property first referred to gives the relation:

$$T = M \frac{x^2}{L^2}.$$

To find M, produce A C to F to meet a vertical through B, the end of curve. Call the algebraic difference of grades (d), then will F B = L d, and since C D = ½ C E by the second property, M = ¼ F B, or M = ¼ L d.

The length of curve, 2 L, may be fixed by the circumstances of the case

or may be found by assuming a certain rate of change of grade per station, the rate of change increasing with (d). Call this rate of change (R), then for L in stations

$$L = \frac{d}{2\,R}.$$

To find the correction at a point one station distant from the P. C. at A, insert the value of (d) and the resulting value for M in the first formula, x being one station; the result is

$$T_1 = \frac{1}{2}\,\frac{L^2\,R}{L^2} = \frac{1}{2}\,R.$$

At two stations from A, $T_2 = 2\,R$; at three stations, $T_3 = 4\frac{1}{2}\,R$; at half a station, $T_{\frac{1}{2}} = \frac{1}{8}\,R$, etc. The table gives values of T for points 50 ft. apart for a few values of L and d. These corrections must be added when the algebraic difference of grades is minus, and subtracted when the algebraic difference is plus.

TABLE NO. 24.—CORRECTIONS FOR VERTICAL CURVES.

Algebraic difference of grades, %.	Rate of change per station, ft.	Horizontal distance from vertex in feet. 0.	50.	100.	150.	200.	250.	300.	350.	400.
		Vertical distance in feet.								
0.3	0.075	0.15	0.08	0.04	0.01	0	...	...	...	...
0.4	.1	.20	.11	.05	.01	0	...	...	...	...
0.5	.125	.25	14	.06	.02	0	...	...	...	...
0.6	.15	.30	.17	.08	.02	0	...	...	...	...
0.7	.175	.35	.20	.09	.02	0	...	...	...	...
0.8	.20	.40	.23	.10	.03	0	...	...	...	...
0.9	.225	.45	.25	.11	.03	0	...	...	...	...
1.0	.25	.50	.28	.13	.03	0	...	...	...	...
1.1	0.1833	.83	.57	.37	.21	0.09	0.02	0	...	...
1.2	.20	.90	.63	.40	.23	.10	.03	0	...	...
1.3	.2167	.98	.68	.44	.24	.11	.03	0	...	...
1.4	.2333	1.05	.73	.47	.26	.12	.03	0	...	...
1.5	.25	1.13	.78	.50	.28	.13	.03	0	...	...
1.6	.2667	1.20	.83	.53	.30	.13	.03	0	...	...
1.7	.2833	1.28	.89	.57	.32	.14	.04	0	...	...
1.8	.30	1.35	.94	.60	.34	.15	.04	0	...	...
1 9	0.2375	1.90	1.46	1.07	.74	.48	.27	0.12	0.03	0
2.0	.25	2.00	1.53	1.13	.78	.50	.28	.13	.03	0
2.1	.2626	2.10	1.61	1.18	.82	.53	.30	.13	.03	0
2.2	.275	2.20	1.68	1.24	.86	.55	.31	.14	.03	0
2.3	.2875	2.30	1.76	1.29	.90	.58	.32	.14	.04	0
2.4	.3	2.40	1.84	1.35	.94	.60	.34	.15	.04	0
2.5	.3125	2.50	1.91	1.41	.97	.63	.35	.16	.04	0
2.6	.325	2.60	1.99	1.46	1.02	.65	.37	.16	.04	0

Curves.

A large proportion of the railway mileage is composed of curves, especially on lines where heavy curvature has been adopted through bad location or to reduce the cost of construction. The maintenance work is usually greater on curves than on tangents for the following reasons: (1) the tendency of the traffic to throw the track out of the line by the pressure of the wheels against the outer rails (in spite of superelevation of rails); (2), the increased wear of rails by (A) the pressure of the wheel flanges, (B) the sliding of the wheels transversely, due to the fact that the axles are not parallel with the radius of the curve, and (C) the sliding of the wheels longitudinally, due to the fact that the outside wheel has to travel on a longer path than the inside wheel in the same time.

The curvature is not usually reckoned by the radius (except in the case

of very sharp curves at yards, etc.), but by the number of degrees of central angle subtended by a chord of 100 ft. The radius of a 1° curve with a 100-ft. chord is 5,730 ft. (or more exactly, 5,729.65 ft.), and the radius on center line (R) or degree (D) of any curve may be obtained by the following formulas:

$$R = 5{,}730 \div D. \qquad D = 5{,}730 \div R.$$

Fig. 208 (diagram 204) shows the various nomenclatures used in curve work. The "central angle" (A) is the angle contained within the radial lines to the extremities of the curve, or the P. C. (point of curve) and P. T. (point of tangent). The "degree of curve" (B) is the portion of the central

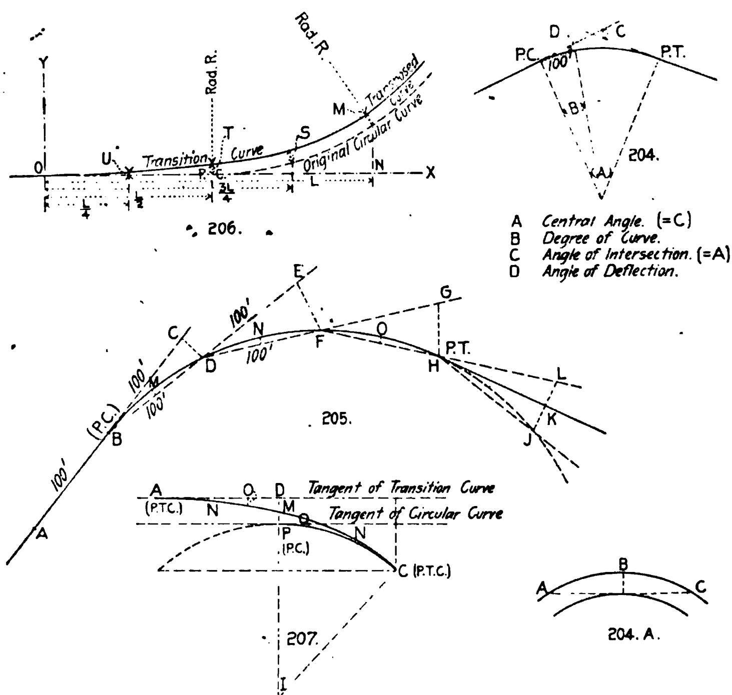


Fig. 208.—Curve Diagrams.

angle which is contained within radial lines to a chord 100 ft. long on the curve. The "angle of intersection" (C) is the exterior angle at the intersection of the two tangents produced, and this angle is equal to the "central angle" (A). The "angle of deflection" (D) is the angle contained within the tangent produced and a 100-ft. chord on the curve. Taking X as the length of curve, in feet; Y as the degree of curve; and Z as the central angle, the relations may be obtained by the following formulas:

$$X = 100 \frac{Z}{Y} . \quad Y = 100 \frac{Z}{X} . \quad Z = \frac{Y\,X}{100}.$$

Table No. 25 affords a handy means of ascertaining the degree of a curve

in the track (see "Lining"). It is based upon that arc of the outer rail which is cut off by a chord tangent to the gage side of the inner rail, the middle ordinate being the gage of the track, as in Fig. 208 (diagram 204, A). The length of the arc may be measured by rail lengths on a short curve; or by feet on a long curve. To find the degree of the curve, stand at a joint on the outer rail and sight across the gage side of the inner rail to the outer rail. Then count the rails between these points, or measure the chord A C, or arc A B C, and the degree of curve will be found in the table.

TABLE NO. 25.—CURVE FUNCTIONS.

Degree of curve.	Radius of center line, ft.	No. of 30-ft. rails in A B C.	Length of— Arc A B C, ft.	Chord A C, ft.	Central angle.— Degs.	Mins.
1	5,730	15.5	463.5	463.4	4	38
2	2,865	11	328.6	328.4	6	34
3	1,910	9	268.1	267.9	8	02
4	1,433	8	232.5	232.2	9	17
5	1,146	7	208.0	207.7	10	24
6	955.4	6.3	190.0	189.7	11	22
7	819.0	5.8	175.8	175.5	12	16
8	716.8	5.5	164.8	164.5	13	08
9	637.3	5.2	155.2	154.8	13	54
10	573.7	4.9	147.5	147.1	14	40
11	521.7	4.6	140.6	140.1	15	22
12	478.3	4.5	134.8	134.3	16	04
13	441.7	4.3	129.5	129.0	16	42
14	410.3	4.1	124.8	124.3	17	20
15	383.1	4.0	120.6	120.1	17	56
16	359.3	3.9	116.8	116.3	18	30
17	338.3	3.8	113.3	112.8	19	04
18	319.6	3.7	110.3	109.8	19	38
19	302.9	3.6	107.4	106.8	20	10
20	287.9	3.5	104.7	104.1	20	40

In Fig. 208, diagram 205 shows how to set out a circular curve. The tangent approach is first carefully lined up and a stake (B) set at the P. C. and another (A) 100 ft. back on the tangent (both on center line of track). The tangent is then lined in for 100 ft. beyond the P. C. at (A), giving point (C). The 100-ft. tape or cord is then held by one end at (A) while its other end is moved inward from (C) for the distance given in Table No. 26 as the tangent deflection on a chord of 100 ft. for a curve of the required degree. This gives point (D) on the curve, and a stake is set at this point. The chord (A D) is then extended to (E), 100 ft. The tape being held at (D), its free end is moved inward from (E) for the distance given in the table as the curve deflection on a chord of 100 ft. for a curve of the required degree. This gives another point (F) on the curve. The curve deflection (E F), (G H) is always twice the tangent deflection (C D), (L K). The points (H) and (J) on the curve are set out in the same way from (F) and (L). If the curve ends at (H), as shown, then from the point (L) the tape will be swung in for the distance previously used for the tangent deflection (C D) and this will give a point (K) on the tangent, 100 ft. from the P. T. at (H). Intermediate points on the curve may be set out by measuring the middle ordinate for each 100-ft. chord, as given by the table, thus marking the points (M), (N), (O). Table No. 26 gives the tangent offset (C D, Fig. 208, diagram 205) for a tangent (B C) and chord (B D), both 100 ft. long, and also the middle ordinate of a chord 100 ft. long, so that the table may be used in setting out curves by offsets or ordinates. In the former case it

must be remembered that the curve offsets (E F), (G H), etc., are double the tangent offset.

TABLE NO. 26.—CURVE OFFSETS AND ORDINATES.

Degree of curve, Deg.	Degree of curve, Mins.	Tangent offset, ft.	Middle ordinate, ft.	Middle ordinate, ins.	Degree of curve, Deg.	Degree of curve, Mins.	Tangent offset, ft.	Middle ordinate, ft.	Middle ordinate, ins.
1	0	0.873	0.218	2½	7	0	6.105	1.528	18¼
1	30	1.309	0.327	..	7	30	6.540	1.637	..
2	0	1.745	0.436	5¼	8	0	6,976	1.746	21
2	30	2.181	0.545	..	8	30	7.411	1.855	..
3	0	2.618	0.654	8	9	0	7.846	1.965	23½
3	30	3.054	0.763	..	9	30	8.281	2.074	..
4	0	3.490	0.872	10½	10	0	8.716	2.183	26¼
4	30	3.926	0.982	..	10	30	9.150	2.293	..
5	0	4.362	1.091	13	11	0	9.585	2.402	29
5	30	4.798	1.200	..	12	0	10.453	2.620	31½
6	0	5.234	1.309	15¾	15	0	13.053	3.277	39¼
6	30	5.669	1.418	..	20	0	17.365	4.374	52½

Sharp curves exist on many main lines, having been introduced either carelessly from bad location or necessarily on difficult location or in order to keep down the grades and reduce the cost of construction. In general, 6° should be the maximum for main track. While there is little practical objection to the free use of curvature on a properly located line, many roads have spent large sums of money in taking out or flattening curves to improve the alinement, especially where there is heavy and fast traffic. The Mexican Ry. has numerous curves of 350 ft. and 325 ft. radius, and while building a difficult tunnel its main line traffic was handled successfully over reverse curves of 150 ft. radius, the traffic being light. Curves of 8° to 15° are used on many mountain lines. The Canadian Pacific Ry. has at one point along the Kicking Horse River, a long curve of 22° (nearly a semicircle); it was laid with a superelevation of 6 or 7 ins., but much grinding took place, and the rails are now level, laid to a gage of 4 ft. 10 ins., with guard rails to both track rails, to guide the wheels and to carry the blind tires. The passage of traffic over this curve has been so satisfactory that a proposed expensive tunnel (through running clay) to take out this curve has not been built. Engines with a wheelbase of 14 ft. 6 ins. pass this curve and the maximum speed is 10 to 15 miles per hour. The train resistance due to curvature is in practice sometimes taken as ½-lb. per degree for each degree of curvature.

Very sharp curves are occasionally required in yards, at Y's, and particularly for spur tracks entering storehouses, grain elevators, factory yards, etc. A single car can be hauled round a curve of 40 ft. radius, as in entering a warehouse, etc., where room is limited and land is valuable. Where trains of two or more coupled cars are run, the radius may be 90 or 100 ft., though there may be occasional trouble from the corners of the cars striking each other, unless long coupling links or bars are used. It is not generally advisable to use four-wheel switch engines on curves of less than 75 ft. radius. The outer rails may be wide and flat to give a bearing to the wheel flanges of cars. On all such specially sharp curves care should be taken to have the curvature uniform and regular, the gage properly widened, rails braced, and guard rails properly set, and the maintenance properly attended to. A curve of 79½ ft. radius at the Atlantic Terminal, Brooklyn, has a gage of 4 ft. 9¼ ins., and a superelevation of 4 ins. Table No. 27 gives particulars of some of the sharpest curves on open track and in yards.

TABLE NO. 27.—SHARP CURVES ON STANDARD-GAGE TRACK.

Railway.	Locality.	Radius, ft.	Sharpest curve Degs.	Mins.
N. Y., N. H. & Hartford	Springfield, Mass.	410	14	..
Lehigh & Susquehanna	Upper divisions	383	15	..
" "	Stony Creek	320	18	..
" "	Butler Branch	310	18	32
Baltimore & Ohio	Harpers Ferry (Md. side)	400	14	22
" "	Harpers Ferry (Va. side)	300	19	10
" "	Ilchester	375	15	20
" "	Y for consol. locomotives	136	43	..
Erie & Wyoming Valley (1)	Dunmore, Pa.	310	18	30
Virginia Central	Over Rockfish Gap tunnel	300	19	10
Virginia Central	Over Rockfish Gap tunnel	238	24	15
Prov., Warren & Bristol (2)	Providence, R. I.	271 to 211	21° to 27°	
Chesapeake & Ohio	Cincinnati	187, 210, 231	30° 50′ to 25°	
Canadian Pacific (3)	Kicking Horse River	260	22	..
Pennsylvania	Centennial Exposition (1876)	300	19	10
Pitts., Ft. Wayne & Chicago	Pittsburg, Pa.	246	23	30
Canarsie & Rockaway	Brooklyn, N. Y.	173	33	15
Brighton B'ch & Coney Island	Brooklyn, N. Y.	55 to 125	104° to 56°	
Manhattan Elevated (4)	New York city	90, 100, 103½, 125	63° to 56°	
New York Central	Grand Central Sta., N. Y.	320 to 400	Main tracks.	
" " (5)	Grand Central Sta., N. Y.	75 and 80	Yard tracks.	
" "	Center St., New York	50 to 60	105° to 96°	
Chic., Mil. & St. Paul	Minneapolis side track	125	47°	
C., C., C. & St. Louis	St. Louis, Mo.	206	28°	
" " (6)	Lafayette, Ind.	240	24°	
" " (7)	Cincinnati, O., yards.	70	82°	
Pitts., C., C. & St. L. (8)	Cincinnati, O., yards	50 and 52	Extend'g 90°	
U. S. Military Ry. (1861)	Petersburg, Va.	50	105°	
Lima & Oroya	Peru	395	14	32
Den. & Rio Grande (3-ft.)	Main track	...	24° and 33°	
Den. & Rio Grande	Quarry tracks	...	35° and 40°	
Mexican National (3-ft.) (9)	Manzanillo	144.3	40°	
Cent. Ry. of N. J. (10)	New York yard	147	39°	
Harlem Transfer (11)	New York yard	90 and 104	63.6° and 55°	

(1). This is a loop of 310 ft. radius, over which consolidation, mogul and eight-wheel engines run without difficulty, and often at considerable speed up to 20 miles per hour. The gage is 4 ft. 8½ ins., and the superelevation of outer rail is 6 ins. The rails are 67 lbs. per yd., and there is no guard rail.

(2). This curve is nearly semicircular, beginning at 271 ft. and gradually reducing to 211 ft. radius for about 90°. Double truck engines are used, but eight-wheel engines were enabled to run by giving the front driving-wheels blind tires 7 ins. wide, while a third and fourth rail were laid on the inside of the curve for the blind tires to run on.

(3). This curve on the Canadian Pacific Ry. has been noted above.

(4). The New York elevated railways have very sharp curves on right angle turns from one street to another. The Sixth Ave. line turns out of South Fifth Ave. by a circular curve of 90 ft. and 109 ft. radius for the inner and outer tracks (112° 13′ and 104° 20′) with short reverse curves of 267.2 ft. and 304.65 ft. radius at each end extending 13° 58′ at one end and 10° 29′ at the other. At Coenties Slip, the Third Ave. line makes a double right angle turn by reverse curves of 125 ft. radius between tracks (or about 48°), and 119 ft. radius of inner track. The first curve covers 92° 45′ and the second 119° 45′. The Northwestern Electric Elevated Ry., Chicago, has maximum curves of 90 ft. radius, with a superelevation of 3½ ins., this being the maximum elevation.

(5). Three spur tracks to the freight warehouse of the Adams Express Co. on the east side of the Grand Central Station yard, New York, are of 75 and 80 ft. radius, and are satisfactory for standard baggage cars, 50 ft. long. A four-wheel yard switch engine, with a four-wheel tender is used, adapted to these curves by lengthening the drawbar so as to separate the end frames by a distance of 16 ins. The ties are 5½ ins. wide, with 4-in. tread, and 1-in. flanges. The wheel gage is 4 ft. 5½ ins. back to back of tires, and the track gage is 4 ft. 9 ins., or ½-in. wide. The driving wheels are 4 ft. 4 ins. diameter, with a wheelbase of 8 ft.; and the tender wheels are 2 ft. 6 ins. diameter, with a wheelbase of 7 ft. 6 ins.

(6). Main track curve opposite station. Superelevation, 2½ ins. Gage wid-

ened ¾-in. Guard rail space, 4 ins., 4-in. plank spiked outside inner rail to take blind drivers.

(7). There are two curves of 70 ft. radius, around which cars pass easily, as well as a pony switching engine with a wheelbase of 7 ft. 6 ins. The shackle bar between the engine and tender was slightly lengthened, and the feed hose transferred from the sides to the center line to prevent the corners from jamming and tearing the hose. Bar links with holes 12 ins. apart are used between the cars to spread them apart and keep the corners from striking. Two to four cars are usually handled. The gage is spead 1½ ins. on these curves.

(8). These two sidings turn out of the street connection railway into a beef storehouse, and have each an angle of 90°. A four-wheel engine with 7-ft. wheelbase has been used, but as the street rails get filled with dirt it is the practice to rope the cars in and out. Engines with six driving wheels work regularly over sidetrack curves of 80 and 100 ft. radius.

(9). This is a terminal loop curve covering an angle of 241° 51.4′. The rails are 40 lbs. per yd., on ties spaced 24 ins. c. to c., with braces on every fifth tie. There is a guard rail on the curve, and one rail for blind drivers on the inside of the outer running rail. The engines are moguls with a driving wheelbase of 12 ft., and the trains range from four 30-ft. box cars of 10 tons capacity and three 42-ft. passenger cars to 20 box cars and 5 passenger cars. There is a descending grade of 0.1% with the traffic.

(10 and (11). These are referred to in Chapter 12. The latter has two concentric tracks with end curves of 90° and 104 ft. radius, surrounding an oval freight house; and there are similar curves connecting with the other yard tracks. The outer rail is elevated 2 ins., and gage widened to 4 ft. 9 ins.

In regard to sharp curves, an item to be considered in questions of widening gage on curves, guard rail space, minimum radius, etc., is the length of lap of the wheel flanges below the rail head, and this is given in Table No. 28, the flange depth being taken as 1⅛ ins.

TABLE NO. 28.—LAP OF WHEEL FLANGES.

Diameter of wheel.	Length of lap.	Diameter of wheel.	Length of lap.
30 to 34 ins.	12 ins.	54 to 60 ins.	16 ins.
35 " 40 "	13 "	61 " 68 "	17 "
41 " 46 "	14 "	69 " 76 "	18 "
47 " 53 "	15 "		

Rail braces are used to support rails on curves, as described in Chapter 6, but for curves of less than 4°, double spiking will suffice. On very sharp curves, iron guard rails are sometimes laid inside the inner rail to prevent derailment, as noted further on. The gage should be widened on sharp curves, as also noted further on.

In tracklaying, as well as in location, it is often desirable to ascertain the divergence of a curve from its tangent, and this is given by the following formula, prepared by Mr. Muenscher:

$$X = 0.875\ N^2\ D.$$

Here X is the offset, or distance of one end of a curve from a tangent passing trrough the other end; N is the length of the curve in chords of 100 ft.; and D is the degree of curvature. Thus the divergence of a curve of 6° from its tangent in a length of 500 ft., will be as follows:

$$0.875 \times 5^2 \times 6 = 131.25 \text{ ft.}$$

By making D equal to the difference of the degree of curvature of two curves of different radius, but having a common origin, X will be their di-

vergence from each other at the end of N stations. In tracklaying, if we make $X =$ the gage of track, and $D =$ the degree of curvature of a turnout track (or corresponding to a given number of frog), N will be the lead of the main track. If X is half the gage, N will be the lead of the crotch frog, and if X is the throw of a stub switch, N will be the free length of the switch rail. The formula is sufficiently accurate for practical purposes, and is of great use in field work, with the aid of a table of actual tangents for a 1° curve. For example, suppose a 5° curve to the right, 8 stations long, has been located, and its extremity falls 28 ft. too far to the right to throw the tangent on the best ground. Making $X = 28$, would give $D = \frac{1}{2}°$, showing that a 4° 30′ curve starting from the same origin would pass through the required spot. Suppose that in the same case the new curve is to commence 200 ft. back of the first one; then the required divergence from the tangent will be $0.875 \times 8^2 \times 5 - 28 = 252$. Substituting this value for X and making $N = 5 \times 2$, gives $D = 2.88 = 2° \ 53'$.

In regard to rail wear on curves, the greatest wear is on the inner side of the head of the outer rail, which has to guide the flanges of the wheels. The corner and side of the rail head gradually wear to conform to the section of wheel fillet and flange, and the top of the head wears so as to give a slope upward from the inner corner. This wear becomes greater as the head wears to the shape of the wheel flange. The inner rail does not get cut away in the same manner, as the flanges run from instead of towards it, but the longitudinal and lateral slipping of the inner wheels, the greater weight and the lateral force of the weight upon this rail wear the head down and deform it, often forcing the metal out in a lip beyond the original line of the side of the head. The pressure against the outer rail, and the weight on the inner rail, with its angular inclination, due to the inclination of the engine by the superelevation, tend to overturn the rail by forcing the outer edge of the flange into the ties and drawing the inner spikes. This has been usually resisted by rail braces on the outside of the rail, but the use of metal tie-plates has been found even more efficient, as they prevent the cutting of the wood of the tie. The work of maintaining the gage on curves may be considerably reduced by the use of tie-plates and rail braces, or on heavy curves by the use of bridle-rods or tie-bars holding the base of the rails like switch rods, there being from two to four bars to a rail length. In European practice, tie-rods through the rail webs are sometimes used on extreme curves.

Transition Curves.

One of the great difficulties in practical track work is to maintain an easy riding track at the connection of tangents with curves where circular curves spring directly from the tangents. The cars will pass as easily and smoothly round a well-laid curve as along an equally well-laid tangent, but there is an unpleasant lurching at each end of the curve, due to the sudden change of direction from rectilinear to circular motion, and vice versa. The effect of this lurching is shown by the increased wear of the rails and disturbance of the track at this point, indicating that a lateral force is exerted which has to be resisted in guiding the train along the track. In very many cases an attempt is made to remedy this by some form of transition or easement curve to connect the tangent with the curve

proper. Where a circular curve is laid out to start directly from a tangent, the foreman will usually ease off the ends to make an easier riding track. This is done by throwing the track inward by means of lining bars, so that the curve is practically extended 100 ft. onto the original tangent. The curve is therefore flattened at this point, which is an advantage in giving an easy change from the tangent to the true curve. It is true that this necessarily sharpens the curve a little beyond the located P. C., but there the lurching or swing is less severely felt as the car has already begun to change its direction. Even if this is not done, the lurching will soon be materially lessened by the traffic slightly shifting the track to the position giving it the easiest path (which is an objectionable means of obtaining a desirable end). The use of the transition curve throws the curve out on the tangent, or makes it longer, which is what the practical trackman does by rule of thumb, as above noted. The curve thus altered rides very much more easily, and it is probable that there are very few curves which are not, intentionally or otherwise, maintained in this condition.

Parabolic curves are sometimes used instead of circular curves, with the idea that they ride more easily. They are, however, of comparatively little effect as far as transitioning is concerned, and the same may be said of the plan of throwing in the whole of the curve except about 100 ft. at each end, connecting with the tangents. Mr. Wellington pointed out in the field book which he left uncompleted at his death, that if to decrease the evil due to the connections at curves, we connect the same tangents and tangent points by parabolic instead of by circular arcs, we shall obtain curves which are of a longer radius at the P. C. and P. T. than the circular arc, but ordinarily only slightly longer. Thus the evils of the transition are only slightly alleviated, and there is the disadvantage that the curve is correspondingly sharpened in the center. While in no case is the amelioration of conditions as to radii considerable, a new and unfavorable effect is created; as the degree of a parabolic curve is constantly changing, and the change is very slow, the angle of the axis of the trucks to the axis of the car is likewise constantly changing, but with extreme slowness. Under these conditions the coefficient of friction between the center plates becomes a maximum, and the flange pressure and danger of the center plates binding and causing derailment are both materially increased. With the parabola, it is true, unlike the circle, it is unnecessary to have the tangents equal, and if unequal tangents are used, we shall at one end of the curve ameliorate still more the transition from tangent to curve, but at the expense of introducing less favorable conditions at the other end. On the whole, the parbola is under no conditions a desirable railway curve, as compared with the circle, even if it were more easy instead of more difficult to lay out.

The best way to lay out the curves (especially for high speed) is to locate or relocate the line with circular curves having easement or transition curves connecting the main circular curve with the tangents. The rail wear and the maintenance work for alinement at curves will be much less on a track thus located, and the trackmen soon come to realize this in its relation to their work. Transition curves should never be lined by eye alone. The transition curves are used either on all curves, or on all over 3° or 4°, and the length may be from 50 to 300 ft., according to the degree

of main curve and the local conditions. On old roadbeds, where no great change in position of track is practicable, transition curves can still be fitted by slightly sharpening the degree and radius of the main curve, and moving the middle of the curve a few inches out and the ends a few inches inwards. Curves thus treated are longer than simple curves, so that in relocation, where reverse curves separated by short tangents occur, the tangents will be still further shortened. Absolute reverse curves cannot be so relocated without increasing the curvatures to get in the necessary length for the transition between them, but such curves so transitioned are very much less objectionable than circular reverse curves of easier curvature and with short connecting tangents. Transition curves should not be used as a means of improving location, but should be confined to their proper purpose. In Wellington's "Economic Theory of Railway Location" the case is concisely stated as follows: "What is wanted is (1) to ease off the curve by a rapidly changing radius for a short distance at the ends—a transition curve; and (2) to leave the great body of the curve of uniform radius." With such a curve the work of the trackmen will be considerably reduced, and there will also be less wear of wheel flanges and rails, and rolling stock. The easement, or transition, may be effected in three ways: (1) By a compound curve, whose ends are of greater radius than the central arc; (2) By compounding short circular arcs of gradually increasing radius, until the radius of the main central arc or curve is reached; or (3) By a spiral curve.

On the Pennsylvania Ry. and some other lines no form of spiral transitioning is used, but on curves of 4°, an easier curve is introduced at each end and compounded with the main curve. The Searles "spiral" (which is of the second class, with arcs of equal length), and the Holbrook spiral, are extensively used, as well as modifications of various "spiral" systems introduced by engineers on different roads. A majority of railways employ one or other of these systems in the alinement of track, although there are some notable exceptions, the objections usually urged by these latter being as follows: (1) The benefits are largely theoretical; (2) the practical effects are obviated by the variable velocity of the traffic; (3) the curves are more difficult to lay out and to maintain in alinement. The first objection can hardly be sustained in the face of extensive experience as to the practical advantages derived, and which are worth much more than they cost. As to the second, while it is true that the easement cannot be made to fit the variations of train velocity, it can be made to fit the prevailing velocity; this same objection would apply to the superelevation on curves; but no engineer would propose to dispense with superelevation. As to the third objection, the computation and field work of location are but little more difficult than for circular curves without easement, the extra trouble being mainly in the plotting. The location is easily made precise enough for all practical purposes, and the maintenance of alinement is no more difficult if the curve is properly and permanently marked and the foreman is required to line by the engineer's stakes and not by his eye. The details of plotting and location may be found in various field books and in works on the transition curves, and would be out of place here. A proper system of transition curves has the practical advantage of greatly simplifying the field work of connecting, adjusting and readjusting lines,

while not adding materially to the time required in the first continuous location. The transition curve is discussed very fully in "Engineering News" of Sept. 20, 1900.

The best transition curve is that on the principle of the cubic parabola, being a short curve of varying radius, which is interpolated between the circular curve and its tangent in order to make the passage from the one to the other less abrupt. It must be such that, starting with an infinite radius (or D = 0) at the P. C. (A), it will have a degree at every point in direct proportion to the distance from the P. C., until, at the P. C. C., where it connects with and becomes tangent to the main curve, it is of the same degree as that curve. Such a curve approximates closely to that of the cubic parabola, and with it the curvature and superelevation commence at the same point, the curve commencing easily, and its degree increasing gradually and uniformly, and yet quickly, until at some point it attains the degree of the main curve, the maximum superelevation being attained at the same point. The main circular curve is then continued until, near its end, it is again run out by a transition curve of decreasing degree into the tangent. The centrifugal force will thus be created gradually, and be exactly balanced at every point by a gradually increasing centripetal force from the superelevation, if the latter is precisely adapted to the speed; or, if not, the aggregate will be less and gradually created. The center plates of the trucks will move through the necessary angle quickly, and then remain unchanged until the curve is left. The conclusions presented by Mr. Wellington in regard to this curve were as follows:

1.—The transition curve will deflect exteriorly from the given main curve, because the rate of curvature becomes continuously less.

2.—It will terminate in a tangent parallel to the given tangent, because the same central angle is consumed.

3.—The offset D P (= O), Fig. 208 (diagram 207), bisects the transition curve A C in M.

4.—The transition curve A C bisects the offset O in M.

5.—At any intermediate points, O O', at equal distances from the corresponding P. T. C.'s, or from the middle point M, the offsets to the transition curve from the tangent, or from the main curve produced, are equal.

6.—The average degree of curvature between the P. T. C. at A and any two intermediate points, O and O', varies directly as the distances to these points from the P. T. C.

7.—The square offsets, O or O', from the tangent or the main curve produced, vary as the cube of the distance from the P. T. C.

8.—Any offset, O, may be used with any curve to connect the main curve with the tangent, and the length of the curve only will vary, varying as the square root of half the length of the transition curve.

9.—The half length (n) of the curve (A M or M C) equals the central angle I divided by the degree of the main curve.

The curve should be permanently staked and marked, and the foreman required to maintain it precisely as laid out by the engineer. The marking may be by monuments of stone or pieces of old rail at the beginning, center and end of the transition curve, with oak stakes or old splice bars placed 30 ft. or 50 ft. apart, and 5 ft. on each side of the center. The length of transition curve varies, some roads specify 30, 50, 60 or 100 ft. per degree of

curve, while others specify a uniform length of 150 to 300 ft. and the Southern Pacific Ry. makes them as long as practicable, but always maintaining at least 60 ft. of the central arc. The transition should be used for curves over 2°, the limit of different roads varying from 1° to 4°. On the Northern Pacific Ry., it is used for all curves of 3° and over, the rate of change per degree not exceeding 1° per 50 ft. chord, except on mountain grades, where the chord may be reduced to a minimum of 25 ft. if necessary.

As a rule, the text-books make this too much of a mathematical ideality, with hair-splitting precision, so that beginners do not realize its importance and get to imagine that its value is purely theoretical, and not to be considered in the field. The curve may be laid out by deflection angles or by offsets, but as the differences of curvature are in most cases comparatively small, and the transit work, if rigorously done, becomes more complex, the offset method is particularly suitable. In all ordinary cases, for moderate length and offsets, the curve is sensibly a parabola, and bisects the total offset. The offsets to the curve from the tangent and the circular curve are equal at equal distances from the extremity of the curve, and the offsets at the quarter points are always 1-16 of the total offset, or almost imperceptible, so that for grading purposes the curve is rarely more than half as long in fact as it is in theory. The track centers as well as grading centers may be laid out by offsets alone in all ordinary cases, with practically perfect accuracy. The objection is sometimes made that the method of laying out the curves by offsets is but a rough approximation to the true curve. Such objections (like those to simple methods of laying out turnouts) are apt to be made on theoretical considerations and without due allowance for the fact that delicate and minute measurements are sometimes out of place and useless in track work. As a matter of fact, many miles of track centers have been run in by this method, and the track is practically equal to that on which the centers have been set directly from the transit, while the cost is very much less. In general, when circumstances permit, the best way for determining a transition curve is to assume a length, and let the offset at the P. C. come where it will, but in many cases this is impossible or inexpedient, and the practical case is that the offset F is given a fixed length, and a curve must be put in to fit it. The offsets should vary approximately as the cube of the degree of curvature of the main curve, and while differences in speed may properly be considered in selecting particular transition curves, that does not prevent the law from being as stated if it is desired to use curves changing in degree by a given quantity in a given distance. The minimum length of offset for a 2° curve, or any other transition curve, should be as large as can be conveniently obtained up to a foot or more, provided high speeds are expected. If they are not expected, or if there are many other much sharper curves, a 2° curve may, without sensible harm, be left without transition curves. In any case it is a waste of time to bother with offsets less than 0.1-in. (or even so small), as, within a year after the track is laid, it will almost certainly, under the trackmen's attention, vary more than that, often four or five times as much. In the application to compound curves, the transition curve to connect two curves, D° and $D^{1\circ}$, is practically identical (as to length and offsets) with one connecting a tangent with a curve whose degree is equal to the difference between the degrees of two curves $(D^1—D)^{\circ}$.

A system of laying out transition curves by offsets based on the cubic parabola, and extensively used on the Oregon Ry. & Navigation Co., was described in "Engineering News," June 22, 1899. The following offset method, which is specially adapted to work on existing track, is given by Mr. David Molitor, and has been used on the German government railways and the Illinois Central Ry. The circular curve is staked out on the ground in the usual manner, stakes being driven at the P. C., and on the tangent at distances $\frac{L}{4}$ and $\frac{L}{2}$, Fig. 208 (diagram 206), and also on the curve at the same distances from the P. C., the distance L being the length of transition curve as given in Table No. 29. Having these five stakes, offsets are measured towards the center of the curve as given in the table, and stakes set at the ends of these offsets are the track centers. The position of the circular curve between its two transition curves is given by the constant offset M. The figures given in Table No. 29 are sufficient for all practical purposes. In the equation for the curve, L R is a constant, 173,800, which is found to give good results without excessive values for M. The length of transition curve is then,

$$L = \frac{173\,800}{r}.$$

For points between O and the P. C. the ordinate U from the tangent is given by formula A, and for points between the P. C. and N the offset S from the circular curve is given by formula B.

$$\text{(A)}\quad U = \frac{X^3}{6\,L\,R} = \frac{X^3}{1,042,800}. \qquad \text{(B)}\quad S = \frac{X^3}{6\,L\,R} - \frac{(X - L)^2}{2\,R}.$$

TABLE NO. 29.—OFFSETS FOR STAKING OUT TRANSITION CURVES FROM CIRCULAR CURVES.

Degrees of curve					Offsets			
					$X = \frac{L}{4}$	$X = \frac{L}{2}$	$X = \frac{3L}{4}$	$X = L$
Degs.	Mins.		Radius, R, ft.	L, ft.	U, ft.	T, ft.	S, ft.	M, ft.
2	00	....	2,864.9	60.7	0.003	0.027	0.051	0.054
2	15	....	2,546.6	68.3	0.004	0.038	0.071	0.076
2	30	....	2,292.0	75.9	0.006	0.052	0.098	0.105
2	45	....	2,083.7	83.4	0.008	0.069	0.130	0.139
3	00	....	1,910.1	91.0	0.011	0.090	0.176	0.181
3	15	....	1,763.2	98.6	0.014	0.115	0.216	0.230
3	30	....	1,637.3	106.2	0.018	0.143	0.269	0.287
3	45	....	1,528.2	113.7	0.022	0.176	0.330	0.352
4	00	....	1,432.7	121.3	0.027	0.214	0.401	0.428
4	15	....	1,348.5	128.8	0.032	0.257	0.481	0.513
4	30	....	1,273.6	136.4	0.038	0.304	0.570	0.608
4	45	....	1,206.6	144.0	0.045	0.358	0.671	0.716
5	00	....	1,146.3	151.7	0.052	0.418	0.783	0.836
5	15	....	1,091.7	159.3	0.060	0.484	0.907	0.968
5	30	....	1,042.1	166.8	0.069	0.558	1.042	1.112
5	45	....	996.9	174.4	0.079	0.636	1.191	1.271
6	00	....	955.4	181.9	0.090	0.722	1.352	1.443

Widening Gage on Curves.

The gage is usually widened on curves, but there is no uniformity in this practice. Some lines with but light curvature widen the gage even on comparatively easy curves, while other lines, abounding in sharp curves, widen it only on sharp curves or even maintain the standard gage throughout. A partial explanation of this diversity of opinion is in the character of the locomotives employed, as the widening is to enable trucks to take a radial

position more easily, and also to enable engines of long wheelbase to pass without undue wear of rails and wheel flanges, or liability to climb the rail. There has existed a general impression, especially among trackmen, that the gage must be widened on curves but that the matter could not admit of and such refinement as mathematical analysis. With more enlightened ideas as to the problems involved in track work, however, this matter has been investigated, with the result that it has been shown to depend mainly upon three factors: (1) the rigid and flanged wheelbase of engines; (2) the clearance between wheel flanges and rails; (3) the distance from center of four-wheel truck to front driving axle, and the side motion of the truck. Thus, with a short wheelbase, or the provision of extra flange clearance or truck side play the widening of gage required on sharp curves may be very much less than where opposite conditions prevail. There is a tendency in the motive power departments to reduce the use of blind tires, and many ten-wheel and consolidation engines now have all the driving wheels flanged, but this imposes severe conditions upon the track and is liable to cause considerable trouble and expense in maintenance. It is true, that a little extra clearance is sometimes given to the front and rear driving wheels. The standard width back to back of wheels is 53⅜ ins. The all-flanged 12-wheel engines of the Illinois Central Ry., with a driving wheel base of 15 ft. 9 ins., have the front and rear drivers 53¼ ins.; two middle pairs, 53⅛ ins.; truck, 53⅜ ins. The all-flanged consolidation engines on the Lehigh Valley Ry. have the front and rear driving wheels 53 ins. back to back, and the others 53¼ ins.; the driving wheelbase is 16 ft. 3 ins. The present practice in gaging wheels gives ⅝ to ⅞-in. clearance on tangents, and there is no necessity for widening the gage of track as long as this gives sufficient clearance between the wheel flange and rail to allow the wheel to travel round the curve in a natural position without binding or exerting undue pressure. The question was discussed in "Engineering News" (New York), Dec. 2, 1897, and Sept. 22, 1898. Formulas based upon the controlling conditions were presented by a committee of the Roadmasters' Association of America in 1898, and are given below, being modified from other formulas worked out by Mr. W. H. Searles. The nomenclature is as follows: D = degree of curve beyond which widening will be necessary; A = distance from driving axle to truck pin; B = driving wheelbase; S = side play of truck; P = play allowed by wheel flanges.

$$D = \frac{956}{A \times B}\left((P - \tfrac{1}{4}) + \frac{\tfrac{1}{2} B S}{A + B}\right). \qquad P = \left(\frac{D A B}{956} - \frac{\tfrac{1}{2} B S}{A + B}\right) + \tfrac{1}{4}.$$

The gage at frogs and switches should be the same as on the adjoining track, but some roads widen the gage at these places. The Atchison, Topeka & Santa Fe Ry., for instance, makes the gage 4 ft. 9 ins. at all turnouts, whether on curves or tangents. The widening extends through the switch and frog and narrows to 4 ft. 8½ ins. in a distance of 30 ft. beyond the frog. The gage of 4 ft. 9 ins. is also used for yard tracks, from which many leads turn out. The widening should be effected by shifting the inner rail outward, keeping the outer rail at a uniform distance from the track centers throughout and using this as the line rail. On several roads the widening is 1-16-in. per degree of curve (or ⅛-in. per 2°) for all curves of 3° and over, while on others an arbitrary widening of ½-in. on all sharp

curves (over 8° to 12°) is specified. The maximum widening for track of 4 ft. 8½ ins. gage is ¾-in. or 1 in. On the Chicago, Milwaukee & St. Paul Ry., the practice was to widen the gage ⅛-in. for 7° curves, and ⅛-in. additional for each additional degree up to ½-in. for 10°, all curves beyond this being widened ¾-in. This was satisfactory with the old round-headed rail, but with the adoption of rails of the Am. Soc. C. E. section the false flanges of worn wheels rode on the rail head and injured it so that the rails soon wore out. The present limit is ¼-in., though this is increased by wear in service. On the New York Central Ry., the rule is to widen the gage ¼-in. for curves of 6 to 10°, ½-in. for 10 to 14°, ¾-in. for 14 to 18°, and 1 in. for 18° and over. On the Atchison, Topeka & Santa Fe Ry., it is ⅛-in. for curves of 1 to 2° (inclusive), ¼-in. for 3 to 5°, ⅜-in. for 6 to 8°, and ½-in. for 9 to 11°. The Southern Pacific Ry. allows an additional widening of ¼-in. beyond that given in the table below, but the gage must never exceed 4 ft. 9¼ ins. On the Illinois Central Ry., the widening is ⅛-in. for 5°, ¼-in. for 6° and 7°, and ½-in. for 8°. Table No. 30 shows the practice of some other roads in this respect:

TABLE NO. 30.—WIDENING GAGE ON CURVES.

Curve. degs.	Widening. Lou. & Nash. in.	Nor. Pac. in.	Ch. & N.W. in.	Can. Pac. in.	Ph. & Read. in.	Sou. Pac. in.
1	..	⅛	..	..	..	..
2	..	⅛	..	..	..	..
3	..	⅛	⅛	..	⅛	..
4	⅛	¼	⅛	⅛	⅛	..
5	⅛	¼	3/16	⅛	¼	⅛
6	¼	¼	3/16	⅛	¼	¼
7	¼	⅜	¼	¼	⅜	⅜
8	⅜	⅜	5/16	¼	⅜	½
9	⅜	⅜	⅜	⅜	½	..
10	½	½	7/16	⅜	½	..

Curve. degs.	Widening. Lou. & Nash. in.	Nor. Pac. in.	Ch. & N.W. in.	Can. Pac. in.	Ph. & Read. in.
11	½	½	½	½	⅝
12	⅝	½	9/16	½	⅝
13	⅝	⅝	⅝	..	¾
14	¾	⅝	..	..	..
15	¾	⅝	..	..	..
16	⅞	..	..	..	..
17	⅞	..	..	..	..
18	1	..	..	..	..
19	1	..	..	..	..
20	1	..	..	..	..

Superelevation on Curves.

On tangents, it is important that the heads of both rails should be kept at the same level, or in the same horizontal plane, so as to insure easy and steady riding of the cars. On a curve, however, the centrifugal force causes the train to tend to travel in a straight line, thus throwing a severe and dangerous pressure of the wheel flanges against the outer rails. To reduce this, the outer rail is elevated above the lower one, thus developing a centripetal force which causes the train to tend to run towards the center of the curve. The amount of this superelevation depends upon the degree of the curve and the speed of trains. The centripetal force may be made theoretically to exactly balance the centrifugal force, but in practice it is difficult to get universally satisfactory results since the important factor of speed is so varying. Fast and slow trains travel over the same tracks, so that it is impossible to exactly adjust the actual elevation to theoretical conditions, but a mean, or compromise, elevation must be adopted, taking into consideration the proportion of fast and slow trains.

The centrifugal force (C) of a moving train is calculated by the followin formula:

$$C = \frac{\text{Weight of train (tons)} \times \text{square of velocity (feet per second)}}{32.2 \times \text{radius of curve (feet)}}.$$

The superelevation (E) to counteract this lateral force, is sometimes taken as 1-10 of the square root of the degree of the curve, giving the ele-

vation in decimals of a foot. It is more usually calculated, however, by one of the following formulas:

$$E = \frac{\text{Gage (or distance c. to c. of rails) in ins.} \times \text{sq. of velocity in ft. per second}}{32.2 \times \text{radius of curve, in feet.}}.$$

$$E = \frac{\text{Square of velocity, in miles per hour} \times \text{distance c. to c. of rails, in ft.}}{1.25 \times \text{radius of curve, in feet}}.$$

$$E = \frac{\text{Chord}^2}{\text{Radius} \times 8}.$$

The location in regard to grades, train service, etc., has also an important relation to the required amount of superelevation. Good judgment must be exercised in giving the elevation according to the location and degree of the curve, the speed, and other local conditions affecting the traffic. In fact the proper elevation for each curve should be made the subject of investigation. Thus, a 6° curve at the top of a grade should have less elevation than a 6° curve on level track or at the foot of a grade. On double track, also, the track on which trains ascend should have less elevation than that on which they descend, as the former will have a lower speed. If the rule of the road or the practice of the enginemen is to reduce the speed on certain sharp curves, then such curves will require a proportionately less elevation than easier curves on which trains are run at normal speed. On sharp curves near stations or crossings, etc., where trains always stop, but little elevation is required, as the speed is slow. The same applies to similar curves near the summit of grades. It is not uncommon, however, to find excessive elevation at such locations, calculated for much higher speeds than can be obtained in service. On single track, a curve in a sag of grades may have the elevation increased to provide for trains making a run at the grade.

Some roads specify but one fixed rate of elevation or one fixed rule, leaving the roadmasters and foremen to vary their practice according to their judgment. Other roads adopt varying rates to suit varying speeds on different parts of their lines. The Southern Pacific Ry. gives the trackmen two elevation tables; one of these is for main lines (except mountain divisions with grades of over 1.8%), and is calculated for a speed of 36 miles per hour; the other is for mountain divisions with grades of over 1.8% and for branch lines, and is calculated for 25 miles per hour. The Northern Pacific Ry. specifies that on mountain grades the elevation must not exceed that for 25 miles per hour. The Baltimore & Ohio Ry. gives two rules; one applies to single track with trains in both directions; the other applies to double track on descending and light ascending grades. The Philadelphia & Reading Ry. specifies that the elevation must be equal to the middle ordinate of a chord whose length is equal to the distance run per second by the fastest train, the maximum being 8 ins. On the Chicago, Milwaukee & St. Paul Ry., the elevation is ordinarily 1 in. per degree up to 4°, 4½ ins. for 5°, and 5 ins. for 6° and upward. Where a greater elevation would be required, the trains must reduce speed. On the high speed lines, however, as between Chicago and Milwaukee, 2° curves have 4 ins. elevation, and ride very easily at 60 to 65 miles an hour. On the Atchison, Topeka & Santa Fe Ry., the rule is to elevate the rail ¾-in. per degree up to 5¼ ins., which is the maximum. Special rules are in force where there are many fast

trains and few slow trains; these run as high as 1 in. per degree in some cases. The New York Central Ry. gives the following elevations, the maximum being 6½ ins.: main passenger tracks, curves under 1°, twice the middle ordinate of a 62-ft. string; 1° and over, middle ordinate + 1½ ins.; main freight tracks, ¾ of middle ordinate; combination tracks, middle ordinate; sidetracks, no elevation. The switchback line carrying the Great Northern Ry. over the Cascade Range has curves of 10° and 12°, with a superelevation of 5 ins., and a widening of ¾-in. There is one 13° curve, which is widened 1 in. The grades are 3½ and 4%, compensated 0.04% per degree of curve. No transition curves are introduced. The track is laid with 80-lb. rails, with 16 ties to a rail length, 6 spikes in each tie and 6 rail braces to each rail.

The practice as to superelevation on different railways varies very considerably. For instance, on the Louisville & Nashville Ry. it begins with ⅞-in. for 15 miles per hour on a 1° curve, and runs to a maximum of 7 ins. on 8° curves. The Northern Pacific Ry., on the other hand, begins with ⅛-in. for 15 miles per hour on a 1° curve, and runs to a maximum of 3 ins. at that speed, for a 20° curve. Its table gives the elevations for curves of 1° to 20° for nine rates of speed. On most railways, there is a standard table of superelevations for different curves and speeds, and such elevation is used as is required by the special conditions at individual curves, for (as already noted) practical considerations of traffic and location, maximum safe elevation, and reduction of speed due to curve resistance, generally necessitate some modification of the theoretical elevation. The tables serve only as guides, therefore, and must not be followed blindly. The elevation is usually calculated for passenger train speeds, so as to ensure easy riding, unless that elevation will be such as to interfere with slow freight trains. The practice on different roads is shown in Table No. 31, but that of the Northern Pacific Ry. is not given in full, the elevations being worked out for nine rates of speed:

TABLE NO. 31.—SUPERELEVATION ON CURVES.

	N.Y., N. H. & H.		Southern Pacific.		Ill. Central.				Louis. & Nash.						Nor. Pacific.		
	Speed, miles per hour.																
	40	50	A[1]	B[2]	30	40	50	60	15	25	35	45	55	65	15	30	50
Degs.	Elevation in inches.																
½	¾	1	½	..	..	..	..	..	..	..	..	..	..	..	....	....	....
1	1½	1¾	1	¾	½	1	1½	2	⅞	1	1¼	1½	1¾	2	⅛	9/16	1⅝
1½	2	2¼	1½	1⅛	..	..	..	..	..	..	..	..	..	..	....	....	....
2	2⅜	2¾	2	1½	1	2	2⅞	3¾	1⅝	1⅞	2⅛	2⅜	2⅝	2⅞	5/16	1 3/16	3 5/16
2½	2⅞	3¼	2½	1⅞	..	..	..	..	..	..	..	..	..	..	....	....	....
3	3⅛	3⅝	3	2¼	1½	2⅞	4⅛	5¼	2⅝	2⅞	3⅛	3⅜	3⅝	3⅞	7/16	1¾	4 15/16
3½	3⅝	4	3½	2⅝	..	..	..	..	..	..	..	..	..	..	....	....	....
4	4	4½	4	3	2	3¾	5¼	6½	3½	3¾	4	4¼	4½	4¾	9/16	2⅜	6⅝
4½	..	..	4½	3⅜	..	..	..	..	..	..	..	..	..	..	....	....	....
5	4⅞	5⅜	5	3¾	2½	4½	6¼	..	4⅜	4⅝	4⅞	5⅛	5⅜	5⅝	¾	3	....
5½	..	..	5½	4⅛	..	..	..	..	..	..	..	..	..	..	....	....	....
6	5⅝	6⅛	6	4½	3	5¼	..	..	5¼	5½	5¾	6	6¼	6½	⅞	3 7/16	....
6½	..	..	..	4⅞	..	..	..	..	..	..	..	..	..	..	....	....	....
7	6½	7	..	5	3½	6	..	..	6¼	6½	6¾	7	..	..	1 1/16	4⅛	....
8	7⅜	7⅞	..	..	4	..	..	..	7	..	..	..	..	..	1 3/16	4 11/16	....
9	..	..	..	..	4½	..	..	..	..	..	..	..	..	..	1 [illegible]/16	5 5/16	....
10	..	..	..	..	5	..	..	..	..	..	..	..	..	..	1½	5 15/16	....
11	..	..	..	..	5½	..	..	..	..	..	..	..	..	..	....	....	....
12	..	..	..	..	6	..	..	..	..	..	..	..	..	..	1¾	7⅛	....
15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2 3/16	....	....
18	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2⅝	....	....
20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2 15/16	....	....

Note.—Southern Pacific Ry.: (A[1]) For main lines, excepting mountain divisions having grades over 1.8%; (B[2]) For mountain divisions having grades over 1.8%, also for branch lines; maximum elevation, 6 ins.

It is, of course, useless to carry out the tables to very high figures, for the elevation cannot be carried beyond certain limits, while on very sharp curves trains are usually required to reduce speed for considerations of safety, so that a less elevation may then be introduced. The maximum allowed should be 6 or 7 ins., though on some roads it is carried as high as 9 ins. The maximum should, however, rarely be used, except on tracks used extensively by passenger trains at high speed, as it is too high for heavy freight trains moving at a moderate speed. If a road has many very sharp curves and operates a high speed traffic, it may be economy to change the alinement, as has been done on many lines within recent years. This point is fully discussed in Wellington's "Economic Theory of Railway Location" (Chapters VIII, XVIII and XIX). If the elevation is too high for slow speeds the weight on the outer rail is reduced, which makes it easier for the wheel flange to mount the rail, and also introduces the liability of getting heavy slow trains stalled on the curve, owing to the severe flange pressure and weight on the inner rail, especially if the grade is not compensated for curvature. There is also a tendency of the ties to shift inwards in the ballast when inclined at a steep angle, which adds to the difficulty of maintaining good line under such conditions. In determining the elevation for a mixed traffic of various speeds, it is best to give greater consideration to the fast than to the slow trains, unless the latter are very numerous and very heavy. Whatever amount of elevation is decided upon, this amount should be maintained uniformly around the curve, as irregularity in this respect seriously affects the riding of the cars, and may introduce an element of danger. For this reason, among others, foremen should frequently test the elevations of their curves.

Sometimes the degree of curve and the proper elevation are marked on a stake driven at each end of the curve (or at the beginning of the curve on double track), or stakes may be set to the required elevation, that is, 0 at the beginning of the curves and the maximum elevation at the point where this maximum is reached. The methods of obtaining the proper elevation are described under "Track Tools" and "Surfacing." Where the degree of curve is not known, the elevation may be ascertained by taking a string of given length, holding the ends to the gage line of the rail, and measuring the ordinate from the center knot to the rail, which will be the required amount. In using the string, measurements should be taken at different points, so that any specially sharp or flat places in the curve (which should be corrected when discovered) do not mislead in setting the elevation. The length of string may be obtained by multiplying the speed in miles per hour by 1.587. The Southern Pacific Ry. specifies the middle ordinate of a string 64 ft. long on main track (based on 36 miles per hour), and 44 ft. long on branch lines (based on 25 miles per hour). The Northern Pacific Ry. specifies lengths as follows:

Miles per hr.	String, ft.	Miles per hr.	String, ft.	Miles. per hr.	String, ft.
20	31.74	35	55.55	45	71.42
25	39.68	40	63.48	60	79.35
30	47.61				

As the superelevation cannot be attained abruptly, it must be carried a certain distance beyond the curve. If the superelevation does not begin until the P. C. is reached, the centrifugal force there suddenly generated

is entirely unbalanced, with the result of giving a dangerous and destructive lurch to the car and a disagreeable lurch to the body of the passenger. If the superelevation is equally divided between certain distances on each side of the P. C. an unbalanced centripetal force is first created, to which the car and passengers adjust themselves, and this at the P. C. is instantly changed into an equally great centrifugal force, with results again disagreeable to the passenger, and productive of almost as much wear and tear, since the sudden twist of the truck remains unaltered, and the sudden reversal of strain from — ½ to + ½ of the centrifugal force has but slightly less injurious effect than the sudden application of the whole centrifugal force where none previously existed. The best and most common practice is to maintain the elevation uniformly over the whole length of the curve, from P. C. to P. T., and then to run it out on the tangent at the rate of 50 ft. in length for each degree of curvature, or ½-in. reduction of elevation in each rail length, or 1 in. in 40 ft. Some roads, however, maintain a uniform run-off, as on the Atchison, Topeka & Santa Fe Ry., where the length is 120 ft., but this gives too steep a grade on sharp curves. When one rail is thus elevated on the tangent, the wheels will tend to run towards the high rail, and they are thus put in the best position for taking the curve. On the New York Central Ry., the run-off is made ¼-in. per 30 ft. for elevations up to 3 ins., and not exceeding 360 ft. for greater elevations. Where easement curves are used, the run-off coincides with them. Compound curves have the elevation distributed half on each section.

These remarks apply to circular curves, but where transition curves are used the run-out should coincide with the transition curve, so that the elevation conforms to the radius at every point, thus getting the best results in every way, as already noted. For such curves, a diagram of the elevation should be given to the foreman. On compound curves, the sharper curve should have the full elevation on its entire length, running out on the flatter curve to the elevation of the latter. On reverse curves, or curves with very short tangents between them, the elevation must be made gradually on the curves, commencing at the point of reverse or at the middle of the short tangent. The high rail should be the line rail, and this rail is usually raised to the required elevation, although on some roads the inner and outer rail are respectively lowered and raised by half the amount of superelevation, for the purpose of maintaining the center of gravity of the train uniform on curve and tangent.

Where curves occur on bridges and trestles, special methods are required for putting in the superelevation. On the New York Elevated Ry. the outer rail is raised by blocks 3½ ins. thick for all curves, which is found to be approximately correct. A greater elevation was at first used on curves of 90 ft. and 125 ft. radius, but this was reduced to 3½ ins. when the rails were relaid. The higher speed on the easier curves compensates to some extent for the uniform superelevation, while the use of only one thickness of block enables these blocks to be cut and stored for seasoning. The superelevation is run out from the P. C. and P. T. on the tangent for a distance of 30 ft. on 90-ft. curves to 50 ft. for 350-ft. curves. Different methods of giving the elevation are noted below:

(1) Shimming on Ties.—A long shim carrying the outer rail and guard

rail is spiked to the tie, but with any considerable elevation the rails get badly worn, as they are vertical, and the heads are not in the same plane.

(2) Taper Ties.—For moderate curves where the ties are carried by stringers, the ties may be cut to a taper, the minimum thickness under the rail being 5 ins. With plate girders where the ties have to be cut out for the cover plates, they would be very weak on the thinner end, while a 14-ft. tie on a 6° curve would have to be 14 ins. thick at the larger end. Such ties are expensive, and must be kept in stock, each curve requiring ties of different thickness. As a matter of fact, comparatively few mills can saw ties to tapered dimensions.

(3) Blocking under Ties.—The most general practice is to use ordinary ties and block them up to the required elevation by blocks on the stringers.

(4) Cushion Ties.—These are made the full width and length of the ordinary ties and are laid upon them. They taper from a thickness of 3 ins. at the small end. They tend to cause decay of the tie and cushion tie by holding water between them, and, being thin, are liable to warp and split.

(5) Cushion Caps.—On trestles, tapered caps may be bolted to the main caps, boxed out 1 in. to 2 ins. for the stringers, but the boxing holds water, and water also gets between the cap and the cushion.

(6) Corbels.—If the trestle is built with corbels, those on the outer side of the curve may be higher or thicker than the others, so as to raise the stringers.

(7) Inclined Trestle.—The mudsills may be inclined to the proper degree of elevation, so that the framing of the bents will not be affected, or the outer posts may be of increased length, keeping the mudsills level. The main objection is, that with slow trains, the weight on the inner rail would tend to throw most of the weight on the inner posts, so that only the sway bracing would resist the racking of the bent, which, with considerable elevation and a high trestle, would be very great. This might be prevented by increasing the batter of the inner posts, but such special construction of bents is undesirable. With a pile trestle, the piles may be cut off at the proper height for framing the caps at the required elevation.

(8) Deck Plate Girders.—The outside girder may be raised by blocking thus giving the proper inclination to the ties, but with trains slower than the speed for which the elevation is calculated, the load would not pass through the axis of the bridge, and would subject the girder to strains not provided for in the construction. A longitudinal timber may be bolted to the top chord of the outer girder, or blocks with inclined top faces may be placed on one or both chords, the latter being the better plan. In rare cases the outer girder is made higher, but this is not an advisable plan, apart from the extra trouble in manufacture for each structure. With truss bridges, however, the outer floor stringer may well be raised, there being no long cover plates, so that the ties are boxed out uniformly.

(9) Solid Floors.—The elevation may be made in the rail bearings if the floor is unballasted, or by inclining the ties in the ballast, if the ordinary roadbed is carried across the bridge.

Guard Rails on Curves.

One other point to which reference may be made is the use of guard rails on curves. This is more common on the sharp curves of yard tracks than

on main track, and the practice is very diverse. They are used on all curves sharper than 10° or 12° on some roads, and 20° to 25° on others. The width of flangeway ranges from 1¾ ins. plus the amount of widening of gage on the curve, to 2½ and 3 ins., and even 5 ins. In some cases it is considered that on all curves sharper than 12° or 15°, an iron guard rail should be laid inside the inner rail to prevent derailment, being so placed as to come into action only as the flange begins to tend to mount the outer rail. This requires a spacing of 3⅛ to 4 ins. For guard rails at frogs and crossings, the flangeway is usually 1¾ ins., but this would be bad practice on ordinary curves, as it would relieve the flange from action and throw all the normal guiding upon the guard rail. It is only admissible to thus throw a guard rail into constant action on extremely sharp curves, such as the 90-ft. curves of the New York elevated railways, where the guard rails are kept well lubricated. On these lines, the flangeway is 2¼ ins. at check rails on curves, and 2 ins. at frogs. On very sharp curves, a guard rail is sometimes laid on the inside of the outer rail (leaving 1¾ ins. flangeway) and another one outside of the inner rail, and as close to it as possible. The object of these rails is to help support the blind or flangeless driving wheels of engines when they have a dangerously narrow bearing on the track rails on these curves.

CHAPTER 21.—TRACK INSPECTION AND THE PREMIUM SYSTEM.

The track is usually inspected daily by the trackwalkers, or by a man sent over the section on a velocipede, and the section foremen and supervisors have to make frequent examinations, not only in detail, but of the general condition of the track and roadway. This examination should be made on foot or from a handcar, but also occasionally from the engine or the rear car of a train, these latter methods giving a broader general view of the work and enabling the foreman to test the riding qualities of his track. The roadmasters and engineers should also make general inspections of the divisions under their charge.

On most roads of importance, especially where the premium system is in force, a general inspection of both the track and the entire property is made once a year by the superior officers, record being kept of the condition of each section, station, etc., year by year. This inspection is usually made in the autumn. A private car with large end platform and windows may be used, or a special car having the floor sloping up from the end and fitted with seats, while the end is either open or fitted with glass windows extending to the floor. The car is pushed ahead of an engine at the rate of 10 to 15 miles per hour, stopping at the end of each section, and the officials' mark, on cards provided for the purpose, their rating of the condition of each section. The division roadmasters, section foremen, etc., do not mark their own divisions and sections. The markings of the cards, are then figured up and prizes awarded according to the averages. In some cases the marking or judging is done by the roadmasters, engineers, division superintendents, etc., and where this practice prevails, the section foremen should be taken over the road after the awards have been made,

so that they can see each other's sections. On the Boston & Albany Ry. there are five prizes for division roadmasters and five (of $50 each) for section foremen, awarded on the following points: 1, alinement and surface; 2, joints and spiking; 3, switches and frogs; 4, ballast and ties; 5, ditches and general neatness and cleanliness of roadway. The highest rating under each head is 10, which would mean perfection, and the inspectors mark according to their opinions. Some roads adopt the method of making the section foremen the judges, each foreman marking on every section but his own, considering this better than to appoint judges from among the roadmasters and division superintendents. The annual inspection is thus made to powerfully educate and arouse the spirit of the foremen, and induces a sharp rivalry. Each man becomes more critical of his own division, and in passing over the divisions he notes certain good and bad points, so that the system tends to make the general practice better and more uniform. It pays to take the foremen over the road together once a year, even if no prizes are given, as it gives them more interest in and knowledge of their work, while an incentive to good work, in the shape of a prize, is a good thing. It is well also, to have a "Premium Section," sign board erected on the section tool house or elsewhere on the section, as the laborers themselves then feel that they are getting some recognition and will work hard to prevent any other section from winning away the premium sign. They will naturally take more pride in their work if it is thus publicly recognized, and the best plans for the premium system are those which make the men participators in the prizes.

On the Pennsylvania Ry., the time for the inspection of the main line is selected by the general manager, governed somewhat by the time the board of directors makes its tour over the lines. It is usually about the middle of October, this time being fixed so as not to have the supervisors and others away from their divisions at the last of the month. The inspection parties are of two classes: 1, The "Limited," in which those officiating comprise officials above the rank of supervisor; 2, the "Unlimited" or "General" in which officials down to and including assistant supervisors participate. The inspection car resembles a large caboose, 36 ft. long. The front end is open, and the floor slopes up by steps from this end to about the middle of the car, so that all the occupants may have a good view of the track. This part of the car is fitted with ordinary car seats, giving accommodations for 28 persons.

It is customary on the Monday of inspection week for the party comprising the "limited" inspection to leave Philadelphia, running special west, arriving at Pittsburg in the evening. This party is made up of the general manager, engineer of maintenance of way, general superintendents, superintendents of the divisions over which the inspection is made, principal assistant engineers and assistant engineers of the main line divisions between Jersey City and Pittsburg. The "general" inspection party is made up of all the participants in the inspection, who meet at Pittsburg prepared to move eastward on Tuesday morning. The movement of the inspection train is as follows: Tuesday over Pittsburg Division, Wednesday over Middle Division, Thursday over Philadelphia Division, Friday over New York Division. The inspection party is carried usually in separate trains, the first train carrying the general manager and his party; the second train

carrying the principal assistant engineer and assistant engineers of all the divisions; the third train all the supervisors; fourth train all the assistant supervisors. These are followed by the track indicator car in charge of the motive power department. The use of this car is not considered as part of the inspection of the road, and has no connection with the annual inspection for prizes. The various branch road inspections are arranged for by the division superintendents and usually follow the main line inspection. These are not held regularly, and not on all of the divisions.

The inspection is done by four committees: (1) Line and surface; (2) joints and tie spacing, (3) ballast, switches and sidings, (4) ditches, road crossings, station grounds and policing. The marking is from 1 to 10, and zero is used where there are no ditches, sidings, crossings, etc. In awarding prizes, committees are appointed on each main line division and so arranged that no officer of the division that is being inspected is a member of any committee on award for that division. The prizes awarded after the annual main line track inspection are as follows, all being for the entire line between Pittsburg and Jersey City: First Supervisor's Prize, $100; for main line supervisor (exclusive of yard supervisors) having best line and surface. Second Supervisor's Prize, $50; for main line supervisor (exclusive of yard supervisors) having "second best" line and surface. Yard Supervisor's Prize, $100; for main line yard supervisor having best line and surface on yard. Foreman's Prize, $75; for main line foreman (exclusive of yard subdivisions) having best line and surface. The premium section is not marked by any sign.

The Wabash Ry. has a complete system of track inspection, and gives enough prizes to make the men take particular interest in their work. Below are given the rules for the annual inspection, which is made in November, being conducted by the general superintendent, accompanied by officers of the transportation, roadway and bridge and building departments, and the superintendent. The train usually consists of a baggage car (used for meals), one or two private cars and a sleeping car.

Track Inspection Rules; Wabash Ry.

The annual inspection shall determine the condition of each section and division of main track and sidings, in the following particulars: (1) Line and surface; (2) level; (3) joints, ties and switches in main track; (4) drainage; (5) policing; (6) sidings (meaning all tracks outside the main track, and these must be inspected, marked and kept separately from markings on main track). These conditions shall be determined by a system of marking, for every mile of road: 10 shall indicate perfection; 5 shall indicate a condition unsafe for a speed of 25 miles per hour, and 0 the worst possible condition; intermediate numbers being used to indicate intermediate conditions.

The annual report shall show the total expense for labor for the year on each mile of main track, and each mile of sidetrack, the rating being determined as hereinafter set forth. The yard sections shall be classified together for the first and second premiums, the same as the districts.

The final rating of each section, for classification, shall be made as follows: The conditions noted under the markings Nos. 1, 2, 3, 4 and 5, shall be reduced to an average rating, which, in a column of the report shall represent the general average for conditions noted on main track. The general average of conditions under marking No. 6, in its column, will indicate the general average of conditions noted on all sidings.

Sections having iron rail shall be allowed one point over steel rail; sections having steel rail in service eight years and upwards, half a point, provided this difference does not increase the result above 10. This point will be added to final average, and will not be noted by the inspectors. The sections on each division roadmaster's territory showing the highest general average shall be rewarded by a premium of $35 to the section foreman, and the second highest average by $25.

(1). Line.—True line means straight line on tangents, and uniform curvature on curves, as far as the eye can detect. When these requirements are fulfilled the condition must be represented by 10.

Continuous and very apparent deviations from the true alinement over the entire length of one mile, which would limit the maximum speed for the safe passage of trains to 25 miles per hour, must be represented by 5.

A condition of alinement which would be difficult for a train to pass, should be recorded as 0.

Conditions intermediate between those described above shall be indicated in the proper ratio representing these conditions.

Surface.—True surface means a uniform grade line between changes of grade, and the conditions must be noted as in regard to Line.

(2). Level.—The inspector must watch the level index, and must note unusual oscillations of the car due to unlevel track on tangents, want of uniformity of elevation on curves, or unequal gage.

If the inspector can detect no vibration or oscillation of the car due to unlevel track, on tangents, and want of uniformity on elevation of curves, he will record the condition as 10, and intermediate conditions must be recorded as already noted.

(3). Joints, Ties and Switches.—A perfect joint is one that is fully bolted and tight. Ties must be properly spaced, as per standard plan, and fully spiked with four spikes in each tie. Ends of ties, one side must be parallel with rail. Switches must be placed exactly as shown in standard specifications. When these are fulfilled the condition must be represented by 10, and intermediate conditions recorded as already noted.

(4). Drainage.—The ditches shall be uniform, free from obstruction, and with sufficient incline to afford proper drainage. Ballast shall be uniform and equally distributed. Any condition less than described in the foregoing will be represented by such fraction of 10 as it bears to the required condition

(5). Policing.—This shall consist of the following items, and a perfect condition in all these respects shall be represented by a marking of 10:

A. Cross-ties and iron must be piled according to the general rules.

B. Grass, bushes and weeds should be kept cut close to the ground within limits of right of way, and not allowed to grow closer than within 6 ft. of the rails. Stumps and logs should be cleared from within limits of right of way.

C. Road crossings must be in accordance with standard plans, and must be clear and safe for the passage of animals and vehicles.

D. Signs must be placed in position as required in standard clearance diagram.

E. Cross and line fences shall be kept in repair after being constructed by fence gang. They shall be of standard plans. Cross fences and cattle guards shall be clear of all grass and weeds, and shall be whitewashed.

Any conditions less than prescribed in foregoing subdivisions will be represented by such fraction of 10 as it bears to the required condition.

Expense.—The section which is maintained at the least expense shall receive 10 points. The amount of expense on each section to be determined as follows: From the aggregate expense of the year shall be deducted the cost of extra work, such as placing ties, rails, ballast, and ditching, for which credit will be made as follows: Ties in rock ballast credited at 20 cts. per tie; ties on gravel, cinder or earth ballast, 8 cts. per tie; rock ballast credited at $2.50 per car, other ballast at $1 per car; rail laid credited at $1.50 per 100 ft.; ditching, at $1 per 100 ft. After this deduction is made the section showing the least expense will be marked 100, which, divided by

10, will give the rating of that section. For each additional $10 of expense over the lowest section for all other sections, deduct one point from 100 points, the remainder, after being divided by 10, shall be the rating of that section regarding expenses on the general report, and shall be recorded as the average expense of all miles on that section.

The inspection committee shall consist of six or more persons, or shall be arranged as shown on the accompanying form. (The form or card is 9½ ins. long, and 6 ins. high, with ten lines under the heading.) The general superintendent will assign duties to inspectors on the day of the inspection. The placing of different members of general committee on the several sub-committees will be performed by the officer in charge of inspection. Each member of these committees will be furnished with a form showing the conditions which he must note, upon which he must indicate the rating of each mile.

The officer in charge of inspection shall take up all forms when rating has been placed thereon, and make a general report to the general superintendent, showing the rating of all sections as hereinbefore described,

District.	Section.	Miles.		Committee No. 1, 2 Persons.			Committee No. 2, 2 persons.	Committee No. 3, 2 Persons.			Expense.	Remarks.
		Main Track.	Side Track.	Line.	Surface.	Sidings.	Joints and Ties Switches in Main Track.	Drainage.	Policing. General.	Policing. Fences	Rating	
				1	2	3	4	5	6	6	7	

........................*Foreman.* ....*Inspector.*

Form of Inspection Marking Card; Wabash Ry.

showing the names of all persons entitled to a premium. The general superintendent will then cause the awards to be made, and have signs placed on sections to which premiums have been awarded, which will indicate the standing of that section on each subdivision.

The form of the report is shown herewith, being printed on sheets about 12 ins. wide and 24 ins. high. The line of the first prize is printed in heavy-faced type, and that of the second prize in italics.

On the Hocking Valley Ry., a circular is issued by the engineer of maintenance of way, to the supervisors and section foremen, giving the results of the inspection and announcing the award. The statement issued in December, 1899, is given below, omitting the list of awards, three to each supervisor's district:

"The ninth annual inspection shows an average betterment in general condition of track of 0.49% over last year, the rating having advanced from 83.37 to 83.86%. There was more marked improvement in ballast and

FORM OF RECORD OF TRACK INSPECTION; WABASH RY.

Dis-trict.	Sec-tion.	Location.	Name of foreman.	Total expense for labor.	L'gth, miles.	Expense per mile for labor.	Rating of sections. Line.	Surface.	Sidings.	Joints, ties, & switches: main track.	Drainage.	General.	Expense.	Aver-age rating.	Pre-mium sec-tion.	Remarks.	Roadmaster.
6th and 7th.	209	Ritchie	N. Anderson	$981.16	6.0	$163.52	9.3	9.3	6.9	8.8	8.8	8.6	9.5	8.742	...	...	John McKeown.
	210	**ESSEX**	**J. DONAHUE**	894.99	6.0	149.16	8.9	8.8	8.5	9.2	9.2	9.0	9.6	9.028	210	First prize	" "
	211	Reddicks	Thos. Ferriter	901.91	6.0	150.31	9.1	9.1	7.0	9.3	9.1	9.2	9.6	8.914	...	...	" "
	212	*Campus*	*J. F. Ricketts*	975.56	6.0	162.59	9.2	9.1	7.0	9.3	9.4	9.2	9.5	8.957	212	Second prize.	" "
	213	Essington	Michael Gust	1,083.25	6.0	180.54	9.2	9.1	7.0	9.3	9.3	9.0	9.3	8.885	...	...	" "

ditches than in alinement and surface. Attention should be directed to more careful spiking and gaging, which are so essential to a perfect line."

The marking card used on the Southern Pacific Ry. has a vertical column for each section, and at the side of the card are printed the points to be marked, with the highest rating (meaning perfection) in each case, as follows: Alinement, 12; surface, 12; drainage, 12; switches and frogs, 10; houses and grounds, 10; spiking, 7; ties, line and spacing, 7; ballast, 7; sidings, 5; material, 5; grass and weeds, 5; road crossings and run-offs, 3; fencing, 3; right of way, 2; summary, 100. No fractions or decimals are used in marking. The tabular statement of the inspection shows the marking for each of these items on each section, with names of foremen, roadmaster, etc. The inspection party consists of all the officers who have jurisdiction over and connection with the maintenance of way department. No special committees are appointed to mark upon certain features of the track; and every person scoring is supposed to give on the score card his views in regard to the condition of all the items above noted. The prizes awarded are a gold medal for the roadmaster having the best division, and silver medals for the foreman having the best section, the foreman having the best section-house, and the pumper having the best pump-house at the time of inspection.

Under the system instituted some years ago by the Savannah, Florida & Western Ry., inspections were made annually by the higher officers and the engineers, and quarterly by the officers of the roadway department. Every mile was marked separately for the following items: (1) line; (2) surface; (3) level; (4) frogs and switches; (5) drainage; (6) policing. The maximum in each case was 10. A committee of two was appointed to inspect and mark each mile for each one of these items. This was considered to give a fairer comparison than when every detail is marked by every inspecting

officer, and when every division or section was judged as a whole, as no man, however energetic and conscientious, can watch mile after mile of track under various conditions, and then give any very reliable opinion as to the condition of several items. By the results of the annual inspection there were awarded five premiums: $100 to the supervisor of the best division; $50 to those of the two next best divisions; and $40 and $20 to the best and second best sections on each division. The section foremen were also classified as first, second or third class, according as the markings for their sections are over 8, over 6, or under 6. At the quarterly inspection, prizes were awarded on each division: $15 to the foreman showing the most improvement; $10 to the foreman having the smallest labor account without deterioration in the condition of his section (but if the section had previously had a low mark some improvement in condition was required to obtain this award); $10 to the foreman making the best progress in bringing the roadbed and track up to the standard condition, and $10 for the foreman having the least expense for tools per man.

Where the railway company does not offer premiums, this is sometimes done by the roadmaster in order to encourage his men to get and maintain good track. In one case of this kind a premium of $250 was awarded to the best section, of which $150 went to the foreman and the balance was divided among the laborers in proportion to the number of days worked by each man during the year. The condition of track and tools, amount expended, number of passes issued, and all matters pertaining to the work should be taken into consideration. All awards of this kind should be made on the principle that the greatest benefits should go to the men who secure the best results per dollar of expenditure, and not merely to those who have the best track, without taking the expense into consideration.

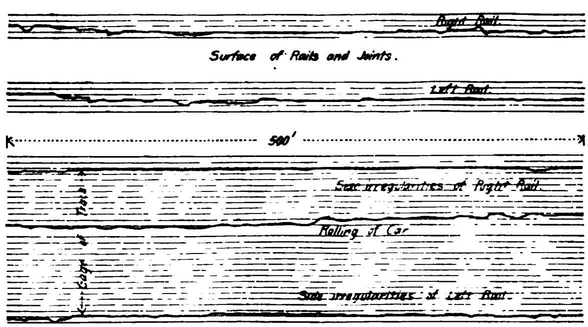


Fig. 209.—Track Diagram of Dynagraph Car; Good 80-lb. Rails.

There is also in force a system of "mechanical inspection" by the use of dynagraph cars. These cars have track connections which follow every irregularity in line, surface and gage, low joints, superelevation of curves, deflection of rails, etc., recording these in diagrams on a roll of paper, and sometimes marking bad spots with a jet of paint on the rail. The car of the Illinois Central Ry. resembles a large freight caboose. Between the trucks is a frame carrying two independent 20-in. wheels which are held in contact with the rails by springs, so as to follow the surface exactly. Their

axles are connected with a cylinder by which all lateral movements of the wheels due to variations in gage are recorded. Similar cylinders receive the vertical undulations of each wheel, which are transmitted by oil pipes to recording cylinders in the car, whose piston rods carry the marking pens. In service, the body is blocked on the trucks, so as to have no motion relative to the wheels, the transverse frame is lowered to bring the 20-in. wheels

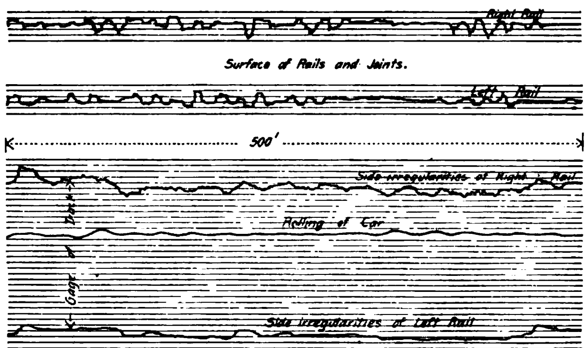


Fig. 210.—Track Diagram of Dynagraph Car; Old 80-lb. Rails.

on the rails, and the car is operated at about 5 to 15 miles per hour. The Pennsylvania Ry. car is carried on only four wheels, and has a pair of small deeply flanged wheels, which are connected with the mechanism of the recording apparatus in the car. A useful device for smaller roads is a simple apparatus which can be attached to a hand car or superintendent's car, and will indicate or record the line and surface and general condition of the track. Mr. D. J. Whittemore, Chief Engineer of the Chicago, Milwaukee & St. Paul Ry., has devised an instrument termed the equilibristat, which can be mounted in this way, and will show the difference in elevation of the rails by the difference in height of the liquid in the legs of a U-shaped tube set transversely to the track. The Chicago Great Western Ry. has a track indicator mounted in a chair car and used for indicating rough spots in the track. The results are good when the car is handled at a uniform speed, but are not very reliable with very fast running or very slow running on curves. The dynagraph car, or recording car, has been applied to street railway service, and one of these is in use on the Chicago City Ry.

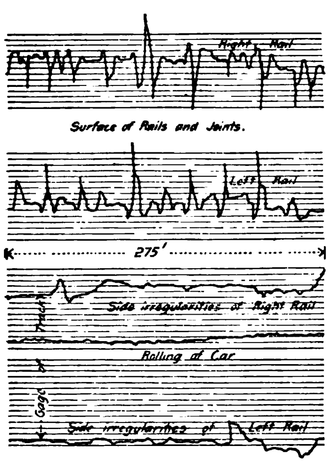


Fig. 211.—Track Diagram of Dynagraph Car; 65-lb. Rails.

The most complete systematic inspections and records are those made with the dynagraph car designed and operated by Mr. P. H. Dudley, who makes

occasional or periodical inspections of numerous roads, and then submits reports based upon the autographic records. The advantages of such inspection for ascertaining the general condition of track and its comparative condition (by comparing diagrams taken at different times) can hardly be overestimated, and this work has aided very materially in bringing the tracks of the New York Central Ry. and Boston & Albany Ry. to the high degree of perfection for which they are noted. The diagrams show the results obtained by new rails and other improvements, the relative economy of which can be thus determined. The work required on the several sections can be seen at once, while the section foremen have their attention called to low joints, low spots, etc., the machine marking deflections even ⅛ or ¼-in. below the normal surface. The foremen will not be governed entirely by this in surfacing, but will know that every paint mark means a weak spot, and that even if the rail appears to be in surface, the ties may be loose and working up and down in the ballast, or the spikes may be loose, and allow the rail to stand free from the tie, which defects they could not detect by sighting for surface. The car has wheel loads of 6,500 lbs. and

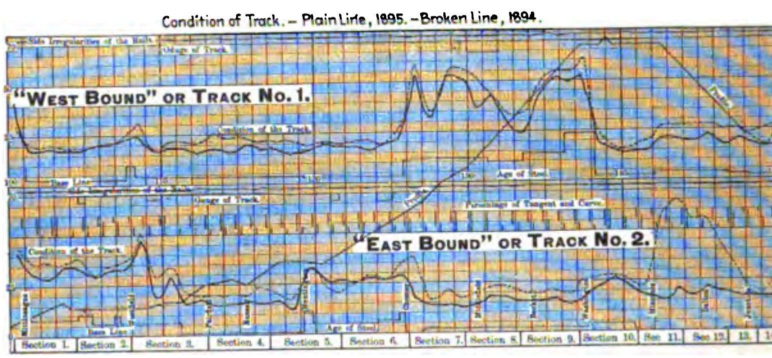


Fig. 212.—Diagram of Comparative Condition of Track of Boston & Albany Ry.; 1894-95.

a special six wheel truck of 11-ft. wheelbase. It is run at a speed of about 30 miles per hour, and each rail records autographically (as a continuous diagram) its condition as to surface, due to the steel, ties, ballast, roadbed and labor. The various undulations are mechanically summed up by the apparatus. Three examples of the Dudley dynagraph diagrams (to a reduced scale) are shown herewith. Fig. 209 is from track laid with 80-lb. rails, 5⅛ ins. high, having three-tie joints; this track is in excellent condition. Fig. 210 is from track laid with older 80-lb. rails, 5 ins. high, also with three-tie joints; these rails were not straightened properly at the mill and had a wavy surface. Fig. 211 is from track laid with 65-lb. rails, 4½ ins. high, with suspended joints; the surface irregularities are very marked. Fig. 212 is a portion of the complete maintenance of way diagram plotted from the records of the detailed diagram. This diagram is for a portion of the Boston & Albany Ry., and compares the condition of the track as shown by the dynagraph car inspections in 1894 and 1895. The following explanation is taken from a statement accompanying the diagram.

The spaces between the vertical lines represent miles of road. The line marked "Condition of Track" for each inspection represents the average sum of all the various undulations of the rails per mile, as mechanically summed up by the inspection apparatus. To plot the sum of the undulations on the diagrams, the number of inches per mile is divided by 176 (the number of 30-ft. rails per mile), which gives the average undulations per rail per mile to 0.01 in. Each horizontal line on the diagrams represents 0.01 in, therefore, as many lines above the base are taken as the average hundredths of an inch of undulation per mile. The results for each track are relative to the base line, yet are comparative one mile with another. The average condition of each mile is indicated from the horizontal line crossed or touched by the "Condition of Track" line in the center of the space for the mile.

The line marked "Age of Steel" for each mile gives the length of service, each horizontal line representing one year. The line marked "Percentage of Tangent and Curve" shows the approximate alinement of both tracks per mile. The percentage of tangent is marked on the left side of the space for the mile, and that of the curvature on the right side. Each horizontal line represents 10% for the mile. The line marked "Profile" shows the grades of the road, and is common to both tracks, though ascending grades on one track are descending upon the other, and vice versa. Each horizontal line represents 10 ft. of elevation, and refers to the Base Line for track No. 2 in all cases.

The line marked "Gage of Track" reads downward from the Base, or 70th line, and shows the amount the track is wide gage, each horizontal line representing 1-10-in. Nearly every mile now shows a perfect gage. For the line marked "Side Irregularities of Rails," above the 70th line, each horizontal line represents 1-10-in. This line reads from the highest point in the center of the space for the mile. These lines are about the best results which can be obtained.

At the end of 1895, 75% of the line was laid with 95-lb. rails, and the track, as well as the diagrams, showed a standard as remarkable as it was gratifying. The full calculated value for heavy and smooth rails shown in 1883, had not only been obtained, but the results were uniform for each division, irrespective of the grades and curves. Such a "Condition of Track" had not been generally believed possible of attainment either here or abroad, and it is evident that similar results could not be produced on either light or heavy round-headed rails. Slipping of the locomotives on the ascending grades had been much reduced. In ten years the undulations of the track had been reduced to one-third of their former amount, even under an increase of double the freight-car wheel loads.

It requires smooth stiff rails, as well as skilled labor, to make a good track. Each year, as the skill of the trackmen increased, it became evident that the condition of the track depended as much upon the condition of the steel as upon the trackman; and to further improve the tracks it was not only necessary to introduce heavier and stiffer rails, but to have them finished smoother at the mills, and, in fact, to manufacture them under conditions which did not prevail before the 95-lb. rails were undertaken in 1890 and 1891. The beneficial results of the work, in raising the standard of surfacing the track and the manufacture of the rails, are clearly defined on the diagram.

CHAPTER 22.—SWITCH WORK AND TURNOUTS.

To divert a train from one track to another a turnout is used, which is essentially a curve connecting the diverging tracks. This curve, however, is built up of (1) a switch to direct the train onto one or other of the tracks as desired, (2) a frog to allow wheel flanges to pass the intersection of the rails, and (3) lead rails connecting the frog and switch. A crossover consists of two turnouts and a short piece of diagonal track, forming a connection between two parallel tracks. A ladder track is diagonal to a series of parallel tracks which are connected with it by turnouts. In all these arrangements, the turnout is the important feature. The lead is that part of the main track rail from the point of switch to the point of frog. The turnout curve (or lead curve) is the turnout rail between the same points. For calculating the length of lead, the turnout curve may be assumed to extend from point of switch to point of frog, giving what is termed the "theoretical" lead. This is too long for ordinary main track frogs (over No. 7) and flattens the curve at the switch. The reason for this is that the switch rail, being of considerable width, and being necessarily set to allow sufficient flangeway space at the heel, cannot be placed in the theoretical line of the curve, but lies several inches within it at the heel. The more general practice, therefore, is to assume that the turnout curve extends from the heel of the switch to the point of frog. This gives what is termed the "short lead." Below are given simple formulas for calculating the lead, in which the nomenclature is as follows: G = gage of track; N = number of frog; T = throw of switch; L = length of switch rail; F = length of frog from point of toe. Of the following formulas, the third is a practical one easily remembered, and its results check very closely with those of more elaborate formulas:

(1) Theoretical lead $= G \times 2 \times N$.
(2) Short lead $= 2\,N\,(G - \sqrt{G\,T}) + L$.
(3) Short lead $= 6\,N + (L + F)$.

Frogs of the same number but of different lengths will have slightly different curves; as will also split and stub switches with the same frogs. The length of lead is practically the same for turnouts from curved track as for those from tangents, and it is of no effect to increase the lead, with the idea of reducing the curvature of the turnout, unless a higher frog number corresponding to the longer lead is used. The curvature of the turnout curve varies on curves: (1) when the turnout is from the inside of a curve, its degree of curvature will be the sum of the degrees of the turnout curve and the main track curve; (2) when the turnout is from the outside of a curve, its degree of curvature will be the difference between the degrees of the two curves. Thus with a No. 10 frog, the curvature of a turnout curve from a tangent will be 6%; from the inside of a 3° curve, it will be $6° + 3° = 9°$; from the outside of a 3° curve, it will be $6° - 3° = 3°$. Where the turnout is on the inside of a main track curve, the frog number should be as high as possible, to keep the degree of curve as small as possible.

The switch rail cannot be planed to a knife edge at the point, but is usu-

ally about ⅜-in. thick at the end, this actual point being some inches back from the theoretical point. At the latter point, the stock rail should be bent carefully with a rail bender, forming a sharp kink which approaches as nearly as possible to the switch angle, care being taken not to simply make a curve. Trackmen are apt to set the switch rail too near the bend, but the point should be 12 to 18 ins. from it. If the length of the switch rail is divided by the difference between the width of its point and the distance between gage lines at the heel, the result will be the "switch number," a function which Mr. W. B. Lee has used in the formulas for short leads given below. The distance between the actual and theoretical points is equal to the width of the former multiplied by the switch number. For any given switch and frog there is only one radius for the arc of a circle which will connect the heel of switch and toe of frog and be tangent at those points, and it is also the maximum. This will be seen from Fig. 213; for if the switch is moved toward the frog, it shortens the tangent distance (T) next the switch, and if it is moved away from the frog it shortens the tangent distance (U) next the frog. To compute the curved and straight leads (A) and (B) and the radius (R) by exact methods requires the use

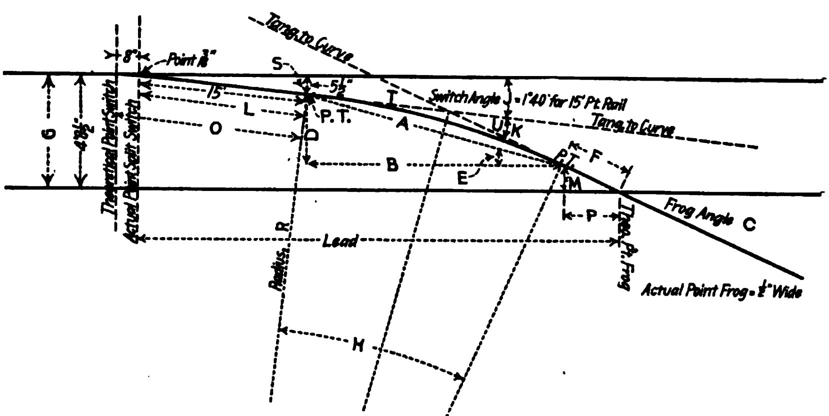


Fig. 213.—Diagram of Turnout.

of trigonometrical functions and preferably a table of logarithms, and these methods are generally used for very exact work. Mr. Lee, however, has developed the following arithmetical formulas which give closely accurate results. With a No. 14 frog, the error is 1 in. in lead and 6 ins. in radius, while the error decreases until for a No. 10 frog it is only 1-16-in. and 1¾ ins., respectively.

$$X = \frac{O}{S}. \qquad N = \frac{F}{M},$$

$$D = G - (S + M), \qquad B = \sqrt{A^2 - D^2},$$

$$A = 2D\frac{X\,N}{X + N}. \qquad R = A\frac{X\,N}{X - N}.$$

The nomenclature for these formulas, and indicated on the diagram is as follows: (A) = Length of turnout curve; (B) = Length of straight rail; (C)

= Frog angle; (D) = Perpendicular distance from heel of switch to toe of frog; (E) = Angle of chord (A) with (B); (F) = Length of turnout side of frog from theoretical point to toe; (G) = Gage of track; (H) = Closure of arc; (J) = Switch angle; (K) = Intersection angle; (L) = Length of switch rail; (M) = Spread of frog at toe (between gage lines); (N) = Frog number; (O) = Distance from heel of switch to theoretical point; (P) = Length of straight wing of frog; (R) = Radius of turnout curve; (S) = Spread of switch; (T) = Tangent from switch; (U) = Tangent from frog; (X) = Switch number. The diagram, Fig. 213, shows a switch with a 15-ft. rail, 5½ ins. spread at the heel, and a switch angle of 1° 40′. Some other formulas relating to this diagram are given below:

(1) Angle K = C — J.	(5) Distance M = F × sine C.
(2) Angle E = C — ½ K.	(6) Distance A = D ÷ sine E.
(3) Lead = L + B + P.	(7) Distance B = D ÷ tan E.
(4) Closure = Arc H.	(8) Radius = ½ A ÷ sine ½ K.

The Hocking Valley gives the following rules:

(1) To find the distance (K) from origin of curve to point of frog.—Multiply twice the gage by the frog number.

(2) To find the radius of turnout curve.—Square the distance K and divide it by twice the gage.

(3) To find length of switch rail.—Square the radius; then square the radius minus the throw of switch; subtract the latter from the former and extract the square root.

(4) To find the distance between the frog points of a crossover, (measured parallel to the tracks) when the tracks are straight and parallel.—Subtract twice the gage from the distance c. to c. of tracks, and multiply the remainder by the frog number. Thus for No. 8 frogs and a distance of 13 ft. c. to c. of tracks it will be:

(13 ft. — 9 ft. 5 ins) × 8 = 28 ft. 8 ins.

Table No. 32 gives the principal elements of certain turnouts of the Lehigh Valley Ry. The spread of the switch at the heel is uniformly 6 ins. Spring-rail frogs Nos. 8, 10, 12 and 15 are used, but the figures given apply to both spring-rail and rigid frogs. For 21-ft. switch rails, the turnouts would be increased as follows:

No. 10 frog	Lead 84.57 ft.;	radius, 717.49 ft.
No. 12 frog	" 94.88 " ;	" 1,052.87 "
No. 15 frog	" 109.03 " ;	" 1,699.53 "

TABLE NO. 32.—TURNOUTS AND LEADS: LEHIGH VALLEY RY.

	Frog									Length of switch rail,	Turnout.			
	Angle		Heel to point.		Point to toe		Heel spread,	Toe spread,			Lead,	Radius,	Curve	
No.	degs.	mins.	ft.	ins.	ft.	ins.	ins.	ins.		ft.	ft.	ft.	degs.	mins.
4	14	22	4	6	3	0	13½	9		10	35.95	114.98	..	..
5	11	29	5	4	3	2	12 13/16	7 19/32		10	41.81	189.63	..	..
6	9	33	6	3	3	9	12½	7½		15	54 50	265.53	21	42
7	8	11	8	0	4	0	13⅝	6 13/16		15	59.84	361 52	15	54
8	7	10	9	0	5	0	13½	7½		15	64.90	473.79	12	07
10	5	44	9	6	5	6	11 13/32	6 19/32		15	74.51	759.16	7	33
12	4	46	11	6	6	6	11½	6½		15	83.53	1146.01	5	00
15	3	49	14	6	7	6	11⅜	6		15	95.72	1959.59	2	53½

For ordinary work and simple turnouts, the actual length of lead is a matter of minor importance, and may be varied several inches, or even feet, to avoid cutting rails or for other reasons of practical convenience. The reason for this is that the rails, being of measurable width, cannot in any case be laid to exactly follow the theoretical lines or center lines, so that a

little variation more or less in either direction makes practically no difference in the turnout. For complicated yard work, junctions, etc., very much closer calculation and measurement are required, as any variation in one part will affect the entire layout. The same is true of street railway work, much of which is built up at the shops like machine work, and sent out so that it can be erected and riveted or bolted up in the field in the same way as bridge work is erected. In laying out yards, shop tracks, terminal connections and complicated work, it is best to plot the plan on a large scale, and then take off the leads, etc., from the drawing.

The following method was adopted in planning and ordering the material for ties, frogs, switches, etc., and in setting out the work for the track men, at the Southern terminal station in Boston, where the tracks are unusually complex. The 8 straight main tracks develop into 28 house tracks. At the throat of the yard these 8 tracks are crossed in both directions by double tracks intersecting each other and having double slip switches at all crossings of the 8 tracks, as described in Chapter 12. A plan was drawn to a scale of ⅛-in. to 1 ft., upon which was a center base line, with 100-ft. stations, points at right angles to this base line being

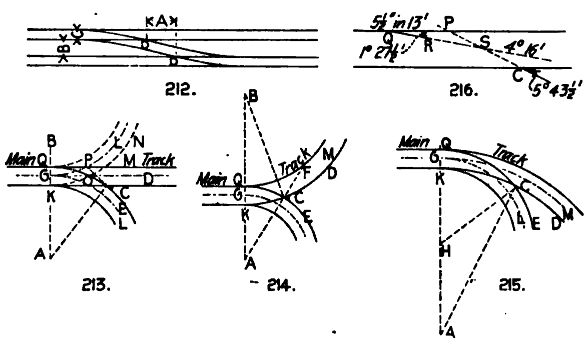


Fig. 214.—Switch Work Diagrams.

designated as so much east or west of certain base line stations. This plan was developed to show each tie and its length, each special timber support for any part of the interlocking apparatus, each switch, frog, guard rail, etc , the station and distance east or west for each switch point, frog point apex and point of curve for each piece of curved track, its radius, signal posts, and signal bridge supports, as well as all grades. All of the calculations for this work were made and checked in the office so that the setting out or staking was such a simple matter that no blunders were made and no other method used in the field than a careful reproduction with the transit and tape of just what was on the plan, using ordinary stakes for line. Later on, when the tracks were raised to grade upon the ballast, grade stakes were set. From this plan all ties and special timbers were ordered, it having been carefully examined for the latter purpose by the signal company. The entire plan was about 24 × 7 ft., divided into several sheets, and was upon tracing cloth for purpose of blue printing.

In Fig. 214, the three lower diagrams (213, 214 and 215) represent the elements of turnouts: K C is the lead, or tangent distance from headblock to

frog point; D C E is the frog angle, and O is the crotch frog, which is 7-10 of the frog angle D C E. It will be seen that the turnout rails should conform to a curve tangent to the main and turnout tracks. If the turnout leaves a straight main track, the frog angle D C E will equal the intersection angle C P M, and the central angle B A C. The turnout curve must be one fitting the tangents Q P and P C. When the main track is curved, and the turnout curves in the opposite direction, the frog angle D C E will be equal to the sum of the central angles A B C and B A C (= F C B). When the main and turnout curves are in the same direction, the frog angle D C E will be equal to the difference between the central angles C H G and C A G (= A C H). The latter arrangement should be avoided wherever practicable, as it sharpens the frog angle, which is always undesirable. With a split switch, the lead K C is from the point of the turnout. With a stub switch, the lead (called also stub lead) is from the headblock, differing from the point lead by the length of the moving rail. As a matter of fact, however, the split switch rail cannot be so thrown as to conform to the theoretical curve if made 15 ft. long, with the splice joint as the hinge. The switch rail is usually taken as a straight line, so that as in Fig. 214 (diagram 216) the intersection angle, R S P, will not be the same as the frog angle, but will be the frog angle minus the switch angle. In other words, the curve must fit the tangents R S and S C, instead of the tangents Q P and P C.

The field work and details of turnouts and switch work will be found in many field books and in Lovell's "Practical Switch Work" and Torrey's "Switch Layouts," and are not intended to be dealt with in this book in any detail. The laying out of switch work is often regarded by engineers and practical trackmen as a very complicated and difficult operation, involving intricate mathematical work. This idea is due largely to the number of formulas and calculations which have been devised by different men. In practical work, however, there is little to choose between them, and a good turnout may be laid out by almost any of the innumerable formulas and tables, for the reason that (within quite wide limits) it makes no particular difference what is the actual length of the turnout lead. In this connection is quoted the following simple and concise statement on "The Art and Mystery of Laying Out Turnout Curves," written by the late Mr. Wellington some years ago:

The theoretical lead = twice No. of frog × gage = 9.42 × No. of frog, for standard gage. This assumes the curve to be a simple circular arc, which is not essential for a good curve, nor does it give the best, and considers the curve to extend back to the heel of the switch rail of a stub switch. The lead is always the same, whether the turnout be from a tangent or a curve. A difference of not exceeding 10% in length of lead, especially if the lead be made longer than above, has no appreciable injurious effect on the character of the turnout curve or on its radius. This is best seen by calling the turnout curve a parabola, and remembering that whether the tangents of a parabola be equal, or one 20% longer than the other, will not affect the excellence of the curve, nor, materially, the sharpest radius. Whether the curve be called a circle or a parabola will not alter its position on the ground by more than a hair's-breadth.

To lay out the turnout curve, the frog being in place, and length of lead given, not differing more than 10% from the theoretical lead. Practically, the best transit for running in the curve, and the only one much used for

fixing points on it, is an experienced eye. On all kinds of turnout curves, whether from straight or curved main track:

Offset from gage side of main rail to gage side of lead rail at middle point of lead = ¼ gage, or 14 ins.; offset at ¼ point of lead = 1-16 gage, or 3½ ins.; offset at ¾ point of lead = 9-16 gage, or 31¾ ins.

Stub Switches.—Main frog to crotch frog = 0.3 of the theoretical lead; length of switch rail = 0.3 of lead and as much longer as convenient; main frog to headblock = 0.7 of lead. Position of crotch-frog not essentially affected by 10% increase of lead, but somewhat farther from main frog (some 3%). The back end of switch-rail should be spiked fast for a portion of its length and it will spring into a circular arc. Calling the switch-rail straight, and starting the lead from it as from a tangent, compounds the curve at the head block and makes the switch-rail a tangent to a new arc. Its practical effect is to lengthen the lead by 6 to 10%, which gives a better curve, not because the assumption on which it rests (that the switch-rail remains straight) is true to fact, for it is not, but because it eases the radius of the first half of the curve. Shortening the lead 10% requires an equal distance near the frog to be tangent to it, and shortens the turnout radius and proper length of switch-rail 20%.

Split Switches.—The gage side of the split rail is straight; therefore it can only be considered, when in place, as a tangent to the true turnout curve. The point at which the theoretical turnout curve attains an offset of the width of a rail head (say 2¼ ins.) from the main line is 0.8 of the theoretical lead from the frog. Hence to obtain the same turnout curve with a split switch as with a stub switch, the lead should be $(0.8 \times 9.42 \times N)$ or $7.54 \times N +$ the length of the plain portion of the head of the point rail. Split switch leads, in other words, other things being equal, should be a little shorter than stub switch leads. But as all turnout curves are improved by being a little longer than a simple circular arc requires, a lead fixed by the rule of $9.4 \times N$ is good practice for split switches.

Radius.—By the principle of proportional triangles it will be seen that the radius = Lead × No. of frog = (No. of frog)^2 × gage. This only holds on turnouts from tangents.

$$\text{Degree of turnout curve} = \frac{\text{frog angle}}{\text{lead in stations of 100 ft.}} = \frac{57^\circ}{N} \div \frac{2\,N\,g}{100} = \frac{606}{N^2},$$

or, in round numbers: 600 ÷ square of the number of the frog. If the turnout be from a curved main track, add to the degree thus obtained the degree of the main curve, if the turnout is to the inside of the curve; and subtract it, if to the outside.

As the frog is straight, it forms a kink or short tangent in the turnout curve. In early practice, trackmen would sometimes spring the wing rail of the frog to conform approximately to the curve, but with modern heavy frogs this is practically impossible, and some roads forbid any attempt at such fittings. It was done by setting the main wing in line with the straight main rail, and bending the end of the other wing by spiking so as to fit the turnout curve. Most men, however, would naturally put in a frog without alteration and fit the curve to it. The kink is of little importance at low speeds, but it has been suggested that it might be well to curve the frogs for crossovers of four track roads through which trains run at relatively high speeds. The frog being a tangent, this tangent should be continued beyond the heel of frog for about 12 ft. for a No. 6 frog to 30 ft. for a No. 15 frog, in order to make an easy riding turnout. This length is the same as the length of tangent in a crossover. In locating sidings, the point of curve back of the frog is assumed at the frog point, and the line is started from the frog and not from the point of switch. If the main line should be a curve in the same direction as the turnout, the frog is then a short tan-

gent between two curves, on one of which it is impracticable to give elevation for curvature, and therefore slow speed is necessary. If the location of the frog point is fixed first, and the frog angle is turned from the main line or from a tangent to the main line at that point, the turnout can be run as easily as any other curve. A table of leads and turnout curves for straight track can be constructed, considering the frog (from heel to toe) as one tangent, and the switch rail (or main line rail for stub switches) as another, and calculating the circular curve required to connect them. Then calculate the offset between the main line and the turnout curve at a point half way between the frog point and heel of switch rail (or headblock for stub switches). This offset will be the same for the same frog, whether the turnout be on either side of the tangent, spiral, or simple or compound circular curve. It should be used in staking out the lead, as it saves the trouble of determining the degree of the turnout curve in the last three cases.

It is usual to issue tables, and diagrams of turnouts, showing leads, etc., and Table No. 33 has been compiled by the author from the standard diagrams of the New York, New Haven & Hartford Ry. The reference letters are given on Fig. 215. The switch rails are all 15 ft. long, except for turnouts with No. 15 frogs, where they are 24 ft. long, 14 ft. being straight and 10 ft. on the turnout curve. All the switches have a throw of $3\frac{7}{8}$ ins. The rigid frogs have a spread of 5 ins. at the toe (G), and 10 ins. at the heel (H),

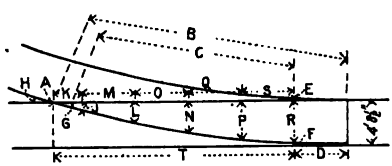


Fig. 215.—Diagram for Turnout Measurements.

while the spring rail frogs have a spread (G) of $9\frac{5}{8}$ ins. With 100-lb. rails the spread at the heel of the switch is greater than with 74-lb. rails. All ties are 7 x 9 ins. The guard rails are 15 ft. long, being straight for 9 ft. with a flangeway of $1\frac{3}{4}$ ins.; each end is flared to give a flangeway of $2\frac{1}{2}$ ins. at 18 ins. from the end of the straight portion, and $4\frac{3}{4}$ ins. at the end of the rail. A guard-rail clamp is placed at each end of the straight portion. (See Chapter 7.)

The method of putting in turnouts by offsets from the main rail to the lead rail is sometimes followed, and this is shown by Table No. 34, the letters in which refer to Fig. 215. The distances given are measured from the gage side of the rail head. These figures may be used on curved as well as straight track, provided the curve is a regular one. If the frog is on the inside of the curve, add the degree of the main curve to the degree of the turnout curve to obtain the curve of the lead. If the frog is on the outside of the curve, subtract the degree of the main curve from the degree of the turnout curve to obtain the curve of the lead, or vice versa. If the turnout is from the inside of a very sharp curve, it is better to use a frog of as small angle as possible, to reduce the curvature in the lead to a minimum. If the turnout is from the outside of a very sharp curve, it is well to put in a frog of such number that the lead will either be straight or curve slightly in the

TABLE NO. 33.—TURNOUTS; NEW YORK, NEW HAVEN & HARTFORD RY.

Weight of rail, lbs. per yd.	74	74	74	100	74	74
Frog number	6	7	8	8	9	10
Style of frog	Rigid.	Rigid.	Rigid.	Rigid.	Rigid.	Rigid.
Angle of frog (A)	9° 33′ 36″	8° 11′ 30″	7° 10′	7° 10′	6° 22′ 10″	5° 43′ 54″
Lead (calculated), point of switch to point of frog (B)	56 ft. 9 ins.	62 ft. 7¼ ins.	68 ft. 2 ins.	66 ft. 3 ins.	72 ft. 9¼ ins.	78 ft. 7¾ ins.
" (calculated), heel of switch to toe of frog (C)	39 " 3 "	44 " 8¼ "	49 " 10 "	47 " 11 "	54 " 0¼ "	59 " 5¾ "
" (actual), point of switch to point of frog (B)	56 " 9 "	63 " 2½ "	68 " 8 "	66 " 8 "	73 " 1½ "	79 " 7 "
" (actual), heel of switch to toe of frog (C)	39 " 0 "	45 " 0 "	50 " 0 "	48 " 0 "	54 " 0 "	60 " 0 "
Rails for lead C (No. and length)	(1) 24, (1) 15	(1) 30, (1) 15	(1) 30, (1) 20 or (1) 26, (1) 24	(2) 24	(1) 30, (1) 24 or (1) 28, (1) 26	(2) 30
Radius of lead curve (C), ft.	284.29	391.99	517.55	517.98	656.33	834.81
Length of switch rail (D), ft.	15	15	15	15	15	15
Throw of switch rail, ins.	3⅞	3⅞	3⅞	3⅞	3⅞	3⅞
Angle between switch rail and main rail (E)	1° 39′	1° 39′	1° 39′	1° 52′	1° 39′	1° 39′
Spread at heel of switch rail (F), ins.	5 9/16	5 9/16	5 9/16	6¼	5 9/16	5 9/16

Weight of rail, lbs. per yd.	74	100	100	74	74	100
Frog number	10	10	10	12	15	15
Style of frog	Spring.	Rigid.	Spring.	Rigid.	Rigid.	Rigid.
Angle of frog (A)	5° 43′ 54″	5° 43′ 54″	5° 43′ 54″	4° 46′ 34″	3° 49′ 12″	3° 49′ 12″
Lead (calculated), point of switch to point of frog (B)	76 ft. 6¼ ins.	76 ft. 1 ins.	74 ft. 1½ ins.	88 ft. 4 ins.	114 ft. 11¼ ins.	111 ft. 7¾ ins.
" (calculated), heel of switch to toe of frog (C)	53 " 6 "	56 " 11 "	51 " 1¼ "	68 " 4 "	84 " 8¼ "	81 " 4¾ "
" (actual), point of switch to point of frog (B)	77 " 2¼ "	75 " 7 "	75 " 7¼ "	88 " 6 "	114 " 10⅛ "	112 " 10⅛ "
" (actual), heel of switch to toe of frog (C)	54 " 0 "	56 " 0 "	52 " 0 "	68 " 0 "	84 " 0 "	82 " 0 "
Rails for lead C (No. and length)	(1)30, (1)24 or (1)28, (1)26	(2) 28 or (1) 30, (1) 26	(2) 26 or (1) 28, (1) 24	(1) 30, (1) 28 and (1) 10,	(2) 30, (1) 24	(1) 30, (1) 28 and (1) 24
Radius of lead curve (C), ft.	750.85	843.36	757.26	1,252.71	1,947.42	1,973.93
Length of switch rail (D), ft.	15	15	15	15	24	24
Throw of switch rail, ins.	3⅞	3⅞	3⅞	3⅞	3⅞	3⅞
Angle between switch rail and main rail (E)	1° 39′	1° 52′	1° 52′	1° 39′	1° 2′	1° 10′
Spread at heel of switch rail (F), ins.	5 9/16	6¼	6¼	5 9/16	3 7/16 at 14 ft., 5⅞ at 24 ft.	3 13/16 at 14 ft., 6 9/16 at 24 ft.

opposite direction from the main curve. The main track should be set to true line before the frog is put in. The measurements are calculated from the theoretical point of frog, but are changed so as to be read correctly from the actual point.

TABLE NO. 34.—LAYING OUT TURNOUTS BY OFFSETS.

Frog	Rigid.	Spring.	Spring.	Spring.
Frog, number	6	8	10	12
Frog angle ....A	9° 32′	7° 10′	5° 44′	4° 47′
Clearance of heel of switch, ...F	5½ ins.	5½ ins.	5½ ins.	5½ ins.
Length of switch rail...........D	15 ft.	15 ft.	15 ft.	15 ft.
Point of switch to point of frog..B	56 ft. 4¾ ins.	65 ft. 6⅜ ins.	76 ft. 8½ ins.	86 ft. 9 ins.
Heel of switch to frog point*...T	41 " 4¾ "	50 " 6⅜ "	61 " 8⅛ "	71 " 9 "
Lead curve	20° 26′	12° 38′	7° 20′	4° 43′
Offset from main rail to lead....J	5½ ins.	10¾ ins.	8½ ins.	7 ins.
" " " " " " L	1 ft. 7¾ ins.	2 ft. 4⅛ ins.	1 ft. 7 ins.	1 ft. 10 ins.
" " " " " " ....N	3 " 4¾ "	3 " 6½ "	2 " 9⅛ "	2 " 10¼ "
" " " " " " ....P	......	......	3 " 1⅞ "	3 " 8 "
" " " " " " ....R	4 " 3 "	4 " 3 "	4 " 3 "	4 " 3 "
Distance, frog point to offset....K	3 " 0 "	7 " 6 "	7 " 6 "	7 " 6 "
" " " " ...KM	11 " 4¾ "	20 " 6 "	16 " 8⅛ "	23 " 9 "
" " " " KMO	26 " 4¾ "	35 " 6 "	31 " 8⅛ "	39 " 9 "
" " " " KMOQ	......	......	46 " 8⅛ "	55 " 9 "
" " " "KMOQS	41 " 4¾ "	50 " 6 "	61 " 8⅛ "	71 " 9 "

*Measured along the rail.

To set out the turnout curve, stretch a cord from the theoretical point of frog (as measured from K. Fig. 214, diagram 215, and marked on rail), to the point of curve Q C or R C, allowing for proper spread of switch rail heel. Divide this distance into four parts, and (for standard gage) set off a middle ordinate of 1.177 ft. and two side ordinates of 0.883 ft. From each of these

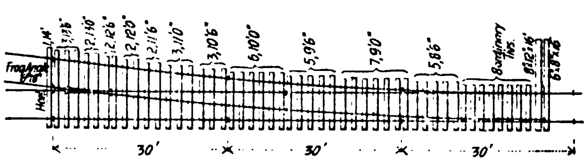


Fig. 216.—Method of Putting in a Split Switch without Cutting Rails; Southern Pacific Ry.

points, and from the frog point and point of turnout, measure half the gage, which will give five points on the center line of the turnout curve. Each side ordinate is ¾ of the middle ordinate. At the middle point of the lead the offset from main rail to turnout rail (gage to gage) is always ¼ the gage, and at the quarter points it is 1-16 and 2-16 the gage, whatever may be the frog number, length or lead, or whether the turnout is from a tangent or curve. The degree of the turnout curve is 600 divided by the square of the frog number (approximately) when the turnout is from a tangent, and this, plus or minus the degree of main curve gives the degree when the turnout is from the inside or outside of a main line curve. The middle ordinate for bending 30 ft. rails is 12 ÷ square of frog number more (or less) than the main curve ordinate, and for other rail lengths, it is in proportion to the square of the respective lengths. If the degree (D) of turnout curve is known, the middle ordinate of a 30-ft. rail is 0.02 D.

When putting in an ordinary turnout, the exact point of commencement is rarely arbitrarily fixed, but may be so located that the heel or toe of the frog can be attached at a rail joint, thus preventing one cutting of the rail. Fig. 216 shows the arrangement adopted by the Southern Pacific Ry. to pre-

vent cutting the rail. Main line rails should never be cut for temporary sidings. From the point selected, measure along the main or straight rail the distance from toe (or heel) of switch to the theoretical frog point, and mark the rail with chalk. Then from this mark measure the distance to the headblock or heel of switch as given by the table. From the headblock the distance c. to c. of ties is marked on the rail flange to facilitate laying. The fact that close accuracy or fine work is not necessary in practical work is recognized on many roads, and the switch diagrams of the Atchison, Topeka & Santa Fe Ry. bear the note that the location of any frog may be varied a foot or two when such change will avoid the cutting of a rail. On this road, stakes for turnouts are always set by the engineering department, which is certainly the best practice.

The rails for the main rail opposite the frog should be put in first, and the switch ties then laid. The frog is then put in place, the switch rails laid and connected up, and the bent rails then laid. The track is then spiked, the turnout rail being spiked snugly to gage at its bend, but not spiked beyond the bend. Then line up the main track, spread the bent rail at the heel of the switch the calculated distance, and line this rail straight from the end to the bend already spiked. The practice of the Boston & Albany Ry. in setting up split switches is as follows: Place the unbroken or main track rail in position, carefully lining it, and spiking as much of it as will not interfere with the switch. Then place the switch in position, and tamp the switch ties and headblock so that they will not shift or settle. Set the point of the switch hard against the main track rail, as if set for the sidetrack, tacking the point and spiking the heel. Erect the gate for this position of the switch, attach the rod, spike the gate to the headblock, and spike the brace plates against the main track rail. Remove the spike from the point and throw the switch by operating the gate. Lay the turnout rail against the point of the switch while in this position and test the gage at the heel. Then spike the brace plates against the turnout rail, and the switch is complete. In the latter forms of the Ramapo switch, however, an adjustable arm is placed on the lower end of the crankshaft in the gate, by means of which the throw of the switch points can be regulated as desired. When using this gate, the operations are as described above, except that instead of laying the turnout rail to suit the switch, it is set to gage, and the throw of the switch is adjusted.

Single switches or turnouts may be put in by measurements only, but for anything more than this, the transit should be used, setting stakes for points of switches and frogs, and for the reverse and tangent points. Where a number of parallel tracks are to be put in, it is customary to stake out the first one, and put in the others by measurement from this. It is always best, however, to set out main line turnouts and turnouts from curves, at least, with the transit. When putting in turnouts with shortened leads, it is only necessary to be careful to place the frog point opposite the stake, letting the switch point come where it may. This in no way disturbs the alinement behind the frog. The short leads may be shortened to economize in cutting the closure rails to fill in between the switch and frog. For instance, a turnout with a No. 8 frog may be laid with a 15-ft. switch rail, a 30-ft. rail, and 15-ft. piece, which with a 15-ft. frog gives a lead of 67 ft. This has been found to work well and to be economical, as

the two pieces 15 ft. 1 in. and 14 ft. 11 ins. long are made from a 30-ft. rail. By putting the shorter piece on the straight lead and the longer piece on the curve, the switch points are kept square across the track. Many roads specify that with spring-rail frogs, the turnout wing rail must be 2 ins. longer than the main line rail (measured from the point), in order to bring the switch points square to the track with the same length of closure rails on both straight and curved leads. In a No. 9 spring rail frog 15 ft. long, the closures will be 50 ft. and 49 ft. 9⅞ ins. By making the turnout wing on spring rail frog, 2⅛ ins. longer than the main line wing, the closure rails can be made the same length. This may be important, as for a No. 10 frog, where two 30 ft. rails sometimes form each closure.

On the Michigan Central Ry., no attempt is made to get the middle ordinate for a lead which is not a simple curve, but the tables showing graphically the standards for putting in switches are based upon the assumption that the proper lead consists of a simple curve uniting the switch rail (or the switch points) with the tangent of the frog leg, and ordinates are given for spiking such leads. Of course the presence of streets and obstructions makes it occasionally necessary or desirable to vary these leads to a greater or less extent. Unless such emergency exists, however, the standard is used, and the foreman's eye has to take care of the particular departure from this standard which he may have to make.

In three-throw switches, Fig. 53, the distance from the crotch frog to the main frog is 0.3 × theoretical lead; or approximately 3 × frog number. In putting in the crotch frog of a three-throw switch, when both of the side frogs are of the same number, put in one lead first and line it up properly. Then take the track gage and move it along the track until the center point is over the center of the lead rail, which will be the place for the point of the crotch frog. Examples of the layout of yard entrances (taken from diagrams issued by the Atchison, Topeka & Santa Fe Ry.) are shown in Fig. 217.

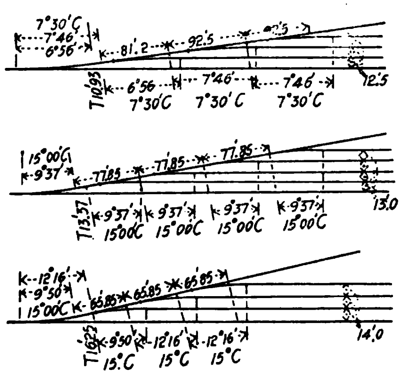


Fig. 217.—Diagram of Yard Entrances; Atchison, Topeka & Santa Fe Ry.

Crossovers.—A crossover is a diagonal track connecting two parallel tracks, and consists of two turnouts which are usually connected by a short tangent, although where space is limited and the crossover is to be used only at slow speeds it may have the turnout curves united as reversed curves, intersecting at a line connecting the centers of the curves. Wherever possible, the crossover should be laid out with trailing switches so as to offer no danger to direct main track movements, being used only by backward movements. The length of the crossover will depend upon the frog number and the distance between tracks (measured between the gage sides of the rail heads). For crossovers between parallel tracks, the distance between the frog points (measured parallel with the rail) is the distance c. to c. of tracks, minus twice the gage, and multiplied by the frog

The rule of the Columbus, Hocking Valley & Toledo Ry. for as- g this has been given above. In Fig. 214 (diagram 212): A = dis- tween frog points (measured along the main track), B = distance 1 gage sides of inner rails of the two adjacent tracks, C = gage of D = frog number. Then: A = (B — C) × D.

a turnout with frogs of different numbers, D and D'; first find the dis- e A for D and for D' by the above formula. Then half the sum of these o distances will give the distance A for the required combination. The diagonal distance D D between frog points is obtained by the following formula:

$$\sqrt{B^2 + A^2}.$$

Table No. 35 gives the distance between actual points of frogs, measured along the rails of parallel tracks, and also the lengths over the switches:

TABLE NO. 35.—CROSSOVERS.

Distance c. to c. of tracks, ft.	ins.	Distance between frog points, No. 7, ft.	ins.	No. 7½, ft.	ins.	No. 9, ft.	ins.
12	6	20	5¼	21	10	26	7½
13	0	23	11	25	6½	31	1¼
15	0	37	9⅞	40	4⅝	49	0¼
18	0	58	8¼	62	7¼	75	11

Frog No.	Distance over switches. Tracks 12-ft. c. to c. 15-ft. switch, ft.	21-ft. switch, ft.	Tracks 13-ft. c. to c. 15-ft. switch, ft.	21-ft. switch, ft.
6	123.96	.....	129.90	.....
7	137.71	.....	144.26	.....
8	150.05	.....	158.00	.....
10	174.52	194.60	184.48	204.60
12	197.85	220.58	209.84	232.53
15	.....	.....	245.00	271.62

Ladder Tracks.—These are diagonal tracks from which a series of parallel body tracks diverge. The angle between the ladder and body tracks conforms to that of the first frog, and all the frogs should be of the same number. Putting in a ladder track at an angle with the body tracks greater than that of the frog angle, will necessitate varying the distance c. to c. of tracks, and requires special formulas for calculating this distance. For ordinary work, the same frogs should be used throughout and the body tracks should be lined in with a transit. Another method is to obtain from a table the perpendicular distance from the gage side of the main track rail to the ladder rail at certain distances along the former. This of course will vary with the frog number, and will give points in the ladder rail. The distance between the frog points is calculated by dividing the distance c. to c. of tracks by the sine of the frog angle. This distance should be measured along the ladder rail, making allowance for the actual or blunt point in the first frog, and then measuring the distances, which will give the positions of the actual points. Stakes may then be set for the points of frogs and switches, using the theoretical leads. The frog point is placed opposite its stake and the point of switch allowed to fall where the shortened lead brings it. A string stretched across the ladder rail parallel with the main rail at a distance equal to the specified distance c. to c. of tracks, will also mark the position of the frog. Stakes should be set to give the line of one of the body tracks, the others being put in by measurements made by the foreman.

On the Michigan Central Ry., the standard practice is to use a No. 11 frog in the main track for all yard leads whenever practicable, and the ladder track layout is made on this basis. In this layout, the angle of ladder

track is 9° 1′; tracks 13 ft. c. to c. and switches 83 ft. apart. The 83 ft. is made up as follows: Lead, 72.43 ft.; frog length beyond point, 8 ft.; straight track to bend in stock rail, 1.95 ft.; bend to switch point, 0.68 ft. In staking out the work, the point of intersection of the center lines of main and ladder tracks is first decided upon, and the location of the No. 11 frog is a very simple matter. Having located this and the P. C. and P. T. of the turnout curve, the transit is set over the point of intersection, the angle of the ladder track turned off, and stakes set along the center line for the headblock, point of frog and point of curve, according to the standard plan. The headblocks are 83 ft. apart. The transit is then placed on the center line of the first body track, opposite the frog point, the angle of ladder is turned off, and stakes for the frog points of the other tracks (83 ft. apart). It is then set on the center line of the track at the point of curve, the angle again turned off and stakes set for P. C. of each track. Finally it is set on the center line of the point of tangent, the angle again turned off, and stakes set (83 ft. apart) for P. T. of each track. The foreman in charge of the work then lays out the switches according to standard offset measurements.

Crossings.—The calculations for crossing frogs at track intersections are apt to be somewhat complicated. The crossings should always be put in

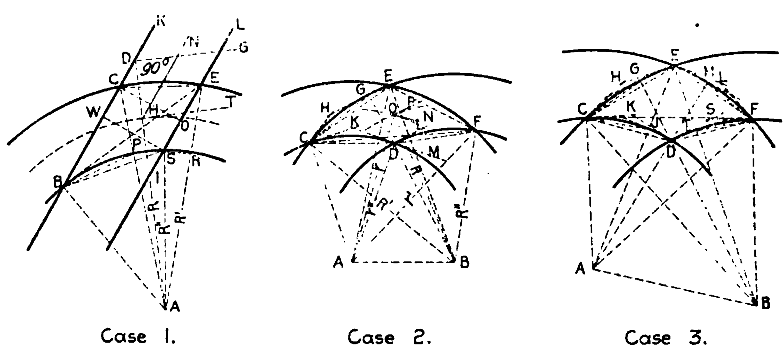


Fig. 218.—Track Crossings at Grade on Curves.

under the direction of an engineer, stakes being set to mark the center lines of the two tracks, and nothing being left to the trackmen to do in the matter of making measurements. Whenever it is necessary to do any lining at crossings, it should always be done with reference to stakes set by the engineers. The degree of curve should be verified by measuring the tangent offset, and by taking supplementary angles checked by measurements with a chain or steel tape. It is impossible to make a satisfactory plan of a curved crossing by taking measurements of the diagonal and of ordinates to the curve. The only proper way is to run out the curve and get the proper angle of intersection, calculate the angles and distances and check these from a large scale drawing. The angle of crossing will be equal to the angle between the radii to the common point. The practice on the Michigan Central Ry. is to take the angle of a crossing frog in the track

with a transit, and then confirm the observed angle by tape measurements. The point is found at which the gage lines of the frog meet, and then a mark is made on the gage side of each rail forming the frog at a distance of 3 ft. from the intersection of the gage lines, measured toward the heel of the frog. The distance between these marks is measured and divided by 6, which gives the line of half the angle of the frog. This angle is of course the angle of the crossing if both tracks are straight lines. If the crossing is formed by one straight and one curved track, or by two curved tracks, the intersection of gage lines at each of the four corners of the diamond is found, also the angle of each frog in the manner stated above. All the connecting distances between the intersections of gage lines are measured, to confirm the calculations, which are anything but simple. As this is a detail of track work not generally treated of outside of railway offices, some particulars are given below and further discussion will be found in "Engineering News," April 21, June 16, July 23 and Sept. 29, 1898. The following three diagrams (Fig. 218) and sets of calculations are given, which represent the practice on the Michigan Central Ry.

Case 1.—Crossing of Curved Track and Straight Track.—Calculation of the Frog Angles and Chord Lengths:

Observe the central angle $\overline{NHT}$.
D, R = radius central curve.
$R' = R + \frac{1}{2}$ gage.
$R'' = R - \frac{1}{2}$ gage.
Let F, F′, F″, F‴ = frog angles at S. B, C and E.

$\overline{NHT} = \overline{KDG}$. $DH = HI = \dfrac{\frac{1}{2}\text{ gage}}{\cos KDG}$. $AD = R + DH$. $AI = R - HI$.

$\overline{CDA} = 90° - \overline{KDG}$. $\overline{EIA} = 180° - \overline{CDA}$.

$\sin \overline{KCA} : AD = \sin \overline{CDA} : R'$ $\therefore$ $\sin KCA = \dfrac{AD \times \sin CDA}{R'}$.

$\sin \overline{KBA} : AD = \sin \overline{CDA} : R''$ $\therefore$ $\sin KBA = \dfrac{AD \times \sin CDA}{R''}$.

$\sin \overline{IEA} : AI = \sin \overline{EIA} = R'$ $\therefore$ $\sin \overline{IEA} = \dfrac{AI \times \sin \overline{EIA}}{R'}$.

$\sin \overline{ISA} : AI = \sin \overline{EIA} = R''$ $\therefore$ $\sin \overline{ISA} = \dfrac{AI \times \sin EIA}{R''}$.

$90 - \overline{ISA} = F$. $90 - \overline{IEA} = F'''$. $\overline{KBA} - 90 = F'$. $\overline{KCA} - 90 = F''$.
To find chord lengths: $\overline{WBS} = F' + \frac{1}{2}(F - F')$. $\overline{OEC} = F''' - \frac{1}{2}(F''' - F'')$.
$\overline{CBP} = F' + \frac{1}{2}(F'' - F')$. $\overline{BPC} = 90° + \frac{1}{2}(F'' - F')$.
$ESR = F + \frac{1}{2}(F''' - F)$. $\overline{SRE} = 90° + \frac{1}{2}(F''' - F)$.

$BS = \dfrac{\text{gage}}{\sin WBS}$. $CE = \dfrac{\text{gage}}{\sin OEC}$.

$\sin \overline{CBP} : \text{gage} = \sin \overline{BPC} : BC$ $\therefore$ $BC = \dfrac{\sin BPC \times g}{\sin CBP}$.

$\sin \overline{ESR} : \text{gage} = \sin \overline{SRE} : SE$ $\therefore$ $SE = \dfrac{\sin SRE \times g}{\sin ESR}$.

To check, compute side BE from the triangle BSE and CBE.

Case 2.—Crossing of Two Curved Tracks.—Calculation for the Frog Angles and Chord Lengths:

Observe the central angle $\overline{NOP}$, or any frog angle, as HCK.
AB = Distance between the centers of the two curves.
R = Longer radius of center line.
r = Shorter radius of center line.
$R' = R + \frac{1}{2}g$, $R'' = R - \frac{1}{2}g$, $r' = r + \frac{1}{2}g$, $r'' = r - \frac{1}{2}g$.

1. If central angle is known, $\overline{AOB} = NOP$. In triangle AOB

$$\tan \overline{ABO} = \frac{r \cdot \sin AOB}{R - r \cos \overline{AOB}}, \text{ and side } AB = \frac{r \cdot \sin AOB}{\sin \overline{ABO}}.$$

2. If a frog angle is observed, as $\overline{HCK}$, find AB in like manner from triangle ABC.
3. All the sides of the triangles ACB, AEB, AFB, and ADB, being known, compute all the angles of each triangle. The angles at C, E, D and F, thus found, will be the Frog Angles required.
4. to find the chord-length CD, produce BD to G; $\overline{KCD} = \frac{1}{2}\,\overline{CAD} = \frac{1}{2}(\overline{CAB} - \overline{DAB})$, $\overline{HCG} = \frac{1}{2}\,\overline{CBG} = \frac{1}{2}(\overline{ABD} - \overline{ABC})$; $\overline{GCD} = \overline{HCK} \pm \overline{KCD} \pm \overline{HCG}$, $CGD = 90° \pm \overline{HGC}$, GD = gage. $\therefore$ from triangle CGD; $CD = \dfrac{\sin \overline{CGD} \cdot g}{\sin GCD}$. Similarly chords CE, EF and FD may be found.
5. Compute value of CF from triangles ECF and DCF to check the work.

Case 3.—Crossing of Two Curved Tracks.—Calculation for the Chord Lengths when the Frog Angles are all known:

$\overline{KCD} = \frac{1}{2}(\overline{CAB} - \overline{DAB})$,
$HCG = \frac{1}{2}(\overline{ABD} - \overline{ABC})$,
$\overline{GCD} = \overline{HCK} \pm KCD \pm \overline{HCG}$,
$\overline{CGD} = 90° \pm \overline{HGC}$,

$$GD = \text{gage}; \quad CD = \frac{g \cdot \sin \overline{CGD}}{\sin GCD}.$$

$\overline{LFE} = \frac{1}{2}(\overline{EAB} - \overline{FAB})$,
$\overline{SFT} = \frac{1}{2}(FBA - EBA)$,
$\overline{EFT} = LFT \pm \overline{LFE} \pm \overline{SFT}$,
$\overline{ETF} = 90° \pm \overline{SFT}$,

$$ET = \text{gage}; \quad EF = \frac{g \cdot \sin \overline{ETF}}{\sin EFT}.$$

$\overline{SFD} = \frac{1}{2}(\overline{ABF} - \overline{ABD})$,
$LFM = \frac{1}{2}(DAB - FAB)$,
$\overline{MFD} = LFS \pm \overline{LFM} \pm \overline{SFD}$,
$FMD = 90° \pm \overline{LFM}$,

$$DM = \text{gage}; \quad DF = \frac{g \cdot \sin \overline{FMO}}{\sin \overline{MFD}}.$$

$\overline{HCE} = \frac{1}{2}(\overline{ABE} - \overline{ABC})$,
$KCJ = \frac{1}{2}(\overline{CAB} - EAB)$,
$\overline{JCE} = \overline{HCK} \pm \overline{KCJ} \pm HCE$,
$\overline{CJE} = 90° \pm \overline{KCJ}$,

$$EJ = \text{gage}; \quad CE = \frac{g \cdot \sin \overline{CJE}}{\sin \overline{JCE}}.$$

Moving Switches by an Engine.—It is sometimes necessary to move a system of switches, or a ladder in a yard, to accommodate some other improvements. If the distance is not too long for a wrecking rope, or combination of short ropes, an engine can pull one turnout at a time readily, and this plan has been followed on the Lehigh Valley Ry. First remove the track intervening between the old and new locations, excavate the ballast to the bottom of the ties, cut the track loose between the turnouts, and put 1-in. boards under the ends of the switch timbers, lapping them in the direction the switch is going to be pulled. Fasten each end of a chain around the rails and sill on each side of the switch, preferably behind a joint, and hook the engine rope to the middle of this chain, so as to prevent the strain from being greater on one side than the other, and thus twisting the switch timbers. The engine will then pull the turnout to its required position. Put in the connecting rails and splice up the track. The engine now moves ahead, prepared to pull each consecutive turnout in like manner. A ladder has been moved in this manner in one day, which could not have been done by hand with the same force of men in ten days.

Instructions for Switch Work.—As already noted, it is the general practice to issue tables and instructions as to details of switch work, and below are given the instructions issued by the engineering department of the Chicago & Northwestern Ry. governing the putting in and the maintenance of split switches, spring rail frogs and movable point frogs:

Rules for Maintenance of Switches and Frogs; C. & N. W. Ry.

In putting in spring rail frogs there should be a full allowance of 3-16-in. clearance left at each end of the frog to the adjoining rails. For a distance of four rail lengths back from the heel of the frog the angle bars should be fully spiked in the slots to prevent, as far as possible, the crowding forward of the main track rails. The anchor block at the spring rail end of the frog should be in every case put in and fully bolted. After the frog is in and oiled up, the spring rail should be tested to see that it moves back to its proper place, and that the side lugs are clear of the caps on the slide plates. In the subsequent care of the frog these lugs should be kept clear of the caps, and the frog kept clean and oiled the same as a split switch.

The spring rail frogs, movable point frogs and split switches should be regularly inspected by the roadmaster to see that all bolts are kept up tight and cotters in place where provision is made for them. Particular attention should be paid to the surface of the ties so that the movable rails have an even and uniform bearing on all of the slide plates. A very common, and also dangerous, condition is that in which the ties at or near the joint fastening become lower than those adjoining them, so that the bent portion of the spring rail of spring rail frogs, and points of movable point frogs and split switches will rise as the wheels pass off from the movable rail at this joint. The middle of the moving rail resting on the high ties, and the point end being depressed to a hollow bearing on the low ties under them, causes the free end to play up and down.

For spring rail frogs on the main track side, a 15-ft. guard rail should be used, which should be placed 1¾ ins. from the gage of the main track rail, the gage of main track being 4 ft. 8½ ins. This guard rail should be placed so that wheels moving toward the point of the frog will be guided from a point 8 ft. in advance of the point of the frog. This will put two-thirds of the guard rail in advance of the point of the frog, and one-third back of it. The guard rail should have not less than four rail braces fully spiked down to support it.

On all split switches there should be a wooden block bedded between the ties under the switch connection rod, clearing the latter by not more than ½-in., and placed 1 ft. from the switchstand, so that if the nut should come off from the lower end of the switchstand stem, the connecting rod cannot drop off from the crank and leave the point loose and free. Where practicable, a better device than this would be to have a bent wrought strap which would be spiked down on the ties and passed under the connecting rod.

Great care should be exercised to see that the gage is maintained true at split switches and at movable point frogs, and that points are kept free from snow and ice and fit snugly against the main rails in either the position for the main track or for the siding.

CHAPTER 23.—BRIDGE WORK AND TELEGRAPH WORK.

Bridge Work.

The maintenance and repair of bridges and trestles is, on large roads, usually in charge of a subordinate department, as noted in Chapter 16, but it is a matter with which the maintenance of way department is intimately connected. The superintendent of bridges and buildings makes periodical inspections, and receives the reports of more frequent inspections made by the inspectors and bridge foremen who are assigned to certain districts. The roadmaster and other track officials also have certain responsibilities as to the bridges. Old structures must be watched and inspected frequently by the men in direct charge, who are not relieved of any responsibility by official inspections. Files of bridge records are usually kept at headquarters describing the character, dimensions, waterway, date of construction, etc., of each individual structure, and similar records are kept by the division officers. In addition to the periodical reports, which are usually made on special blank forms, special reports should be made upon every piece of renewal or reconstruction as soon as completed.

On the Atchison, Topeka & Santa Fe Ry., a bridge inspector is appointed by and reports to the general foreman of bridges and buildings on each operating division; he is an experienced bridge carpenter, selected with regard to his fitness for the work. It is his duty to examine all bridges, trestles, culverts, cattleguards, stock yards and buildings, taking the main line first and the branches in the order of their importance. He begins about the first of each month, and completes his inspection about the end of the month making a daily report by mail and sending in his notebook every week to the general foreman, who examines and signs it, and passes it to the resident engineer to be examined and filed. Besides this, an inspection is made in April by the general foreman, roadmaster, resident engineer and bridge inspector, and another in October by the same officers accompanied by the the superintendent, at which time all important repairs and renewals for the coming year are considered and determined upon, and a complete report on the same made to the general superintendent. On this road, also, all erection is done by three permanent bridge gangs, composed of the best class of men, and the work is found to cost less than if done by contract.

On the Southern Pacific Ry. the bridge superintendents inspect all truss bridges at least twice a year, while every opening must be inspected and reported upon quarterly by a foreman. This latter report must specify, by number, all structures that require renewal within the next quarter, trestles and truss bridges being kept separate. On the Illinois Central Ry., the assistant supervisors of bridges make complete examinations once in three months, and the bridge foremen every month. On the Northern Pacific Ry., the supervisors of bridges make an inspection in January of all truss bridges and large trestles, while in September they, with the division engineers, make an inspection of all bridges, culverts, waterways, etc. This latter inspection is made with special reference to estimating the cost of renewals and repairs required during the ensuing year. On the New York

Central Ry., the supervisor of bridges makes a personal examination of every structure during the last three months of the year, and reports through the division engineer to the chief engineer. He also makes three quarterly reports upon examinations made by himself or his inspector.

On the Erie Ry., the bridge inspectors report monthly to the roadmasters, and the latter report quarterly to the superintendents. The roadmaster's report is in sheet form, 28 x 20 ins., with columns for remarks by the roadmaster, division superintendent and engineer of maintenance of way, a column for "action under train," and 12 columns for general conditions of (1) masonry, (2) bed plates, (3) rollers and frames, (4) pedestals, (5) main trusses or girders, (6) lateral system, (7) metal floor system, (8) wooden floor system, (9) rivets, (10) hangers, (11) castings, (12) paint. A smaller form is used by the inspector in making his reports to his roadmaster or division engineer. The quarterly reports go from the division officers to the engineer of maintenance of way, thence to the general superintendent and the chief engineer, who refers them to the bridge engineer. On the larger divisions, there are bridge inspectors constantly on the line, and if need be they make special reports. On the divisions where the traffic is lighter, the master carpenters make these reports. If a defect develops which the division employees are not well prepared to cope with, they call upon the bridge department for help, which it is well prepared to give, as the Erie Ry. erects all its own bridges, and has two or more gangs of competent bridge men constantly at work. This possible use to which a well-equipped and intelligent gang of bridge men can be put is one of the reasons why it is desirable for a railway company to handle its own metal work.

Every drawing of the bridge company is approved by the bridge department in its pencil form, and the mill order is then made from it by the bridge company, which then makes tracings at its leisure. The mill inspection is let to an inspection firm, which receives from the bridge company (direct) copies of all mill orders. When the metal commences to arrive at the shops, the tracings have been made and approved and prints are then placed in the hands of the railway's shop inspectors. These prints are sent to the bridge engineer the day the metal is shipped from the bridge works, and are then placed in the hands of the erector. Thus the same set of plans follows the work from the time the templates are commenced until the metal is erected, and the erector has the benefit of any remarks the shop inspector may have made upon them.

All test reports are checked and filed carefully in the bridge department against their respective bridges; and tissue copies of shop invoices are filed at once in the department, the hard copies being sent to the field for check and return. Upon their return from the erector, they are filed in place of the tissues; and all plans relating to the structure (masonry, profiles, metal, etc.) are filed under one cover, which is of tough brown paper the size of the sliding shelf drawers. Thus they cannot slip about in the drawers, in which they are all laid flat. The plans of falseworks are bound in sets for the divisions of the railway.

The inspector should keep a uniform record of his inspections, entering the date, bridge number, general condition, and details of any defects that require attention. This book may be a copy of the bridge and trestle record, with a blank page for notes. He signs the book at the end of the trip and

sends it to the superintendent or to the bridge foreman. In the latter case the foreman takes note of the repairs required, etc., and then forwards the book to the roadmaster or superintendent, who has it filed or copied into the permanent bridge record books. The inspector's record should be so complete, clear, and systematic that when the bridge gang starts out its foreman has full details and can arrange to finish up all work at one place at a time, thus avoiding waste of time in traveling to and fro, except, of course, that any emergency work should be attended to first. Every opening, however small, should be given a number for ease of reference and location. Most roads issue special instructions as to bridge inspection, and have blank forms for reports and records.

The inspector usually travels on a hand car, and is accompanied by the bridge foreman of the division and four bridge men who run the car, assist the inspector, and make any minor repairs that are likely to be overlooked later or which require prompt attention. It is sometimes considered best to have two inspectors work together, the reports representing their joint opinions or judgment. The tools include a brace and bits; two or three ½-in. crank augers, 4½ ft. long, to be used in boring timbers; and two ¾-in. octagon steel bars 4 to 5 ft. long, for sounding timbers. One bar has a ball head 3½ ins. diameter for sounding timbers and piles, and the other end is diamond pointed. The other bar has one end like a pinch bar and the other either diamond pointed or flattened to make a scraper for removing sap rot, etc. The diamond point is used for sounding rotten portions. In sounding with the ball head, solid timber will give a firm ring, while rotten wood will give a muffled sound. In boring timber to ascertain its condition, the holes should always be bored from the bottom of the timber, or in an upward inclined direction, so that water will not lodge in them. For iron work, there are required light hammers for testing rivets and light cold chisels for removing rust scale. In testing rivets, the rivet head should be struck a smart light blow sideways, the inspector holding his fingers on the same head and plate at the opposite side from which the blow is struck. Loose rivets should be marked with paint at once. There should be on the hand car a 50-ft. tape, 2-ft. rule, plumb-bob and line, monkey wrench, small broom for cleaning dirt from corners, etc. Also paint pots, brushes and stencils for renewing bridge numbers, unless this work is done at other times by the foremen and bridge gang. The inspector should watch every large structure during the passage of a fast train, noting any undue deflection, swaying or vibration, or any significant movement or sound, and it may be necessary at times to test the deflection under load. The track should be in good line and surface on the bridge and approaches, and well bedded on the latter, so as to avoid heavy shocks from trains running onto the bridge at high speed.

Trestles.—These have usually an average life of 7 to 10 years, the piles being the first part to decay in pile trestles. Where the amount of trestle work or timber structures is comparatively small, the bridge foreman may attend to the inspection, but it is usually best to have as inspector over the foreman a skilled bridge man, familiar with strains, designs, shop work, field work, timber framing etc. On roads where there are many trestles, especially where damp and marshy conditions tend to induce decay, constant inspection and frequent repair must be made to keep the road in safe

condition. In addition to the more or less frequent examinations, there should be an annual or semi-annual inspection in which the alinement and settling are noted, also vertical positions of bents, conditions of all piles (especially at the water line), timbers, foundations, joints, tenons, braces, corbels, etc., especially where they cross or are framed, the timbers being bored when necessary to ascertain the condition. A written report should then be made as to each bridge, accompanied by a record of the principal members, special marks indicating whether they will require renewal in 3, 6, 9 or 12 months, or are safe for more than a year. On large trestles the bents may be numbered. Mudsills are sometimes laid in open trenches, sheathed with planking, but if buried, the mudsills, feet of posts, etc., should have the earth cleared away for a depth of 18 to 20 ins., so that they may be inspected for dry rot; all sap rot should be scraped away to see how much good timber is left. Boring holes in suspicious looking places, especially near the bridge seats and caps, and at the ends of stringers, and braces, will reveal the condition of the timber. The alinement, level or settlement should be observed, as also whether the bents are plumb, and if the ends are firmly supported by the banks. The sway bracing should be well bolted or spiked. The floor system should be examined as to its condition and to see if the stringers have full bearing on the caps and the caps on the piles; also that the full number of bolts, nuts and washers are in position. Barrels filled with water with a floating lid and a fire bucket to each barrel, should be kept on wooden structures of any length.

Wooden Bridges.—In inspecting truss bridges it should be seen that the trusses have the proper camber, and are vertical, that the chord bolts are snug and the lateral rods properly adjusted. Then the truss rods should be adjusted until the counterbraces have a firm bearing on the angle blocks, and all the rods have the same tension. The timbers, seats, and joints should be carefully examined for cracks, splits or rot. Whenever splices exist in bottom chords, and principally in long span bridges, where they generally occur in every panel, it is important to examine them thoroughly, and to note if they are pulling apart, which would indicate a weakness or a defective clamp. The braces and counterbraces should always have a square and even bearing upon the angle blocks, and the sliding from their true position would be sure evidence that the bridge needs immediate adjustment. Such adjustment should never be done by the foreman, but only under the supervision of the bridge inspector. The truss rods, etc., should not be left loose, and should not be tightened while a load is on the bridge. Wooden bridges should be whitewashed inside and outside twice a year. It is well to replace timber stringers of short spans with short plate girders or a solid floor of old rails, reducing the work of the bridge men and the danger from fire, besides making the track more uniform.

Steel Bridges.—The bed plates should be perfectly level and clean; the rollers clean and free to move, and their axes should always be kept at a right angle to the line of the bridge. The pedestals should be free from all cracks and flaws, and have a uniform bearing upon all the rollers or upon the bed plate at the fixed end. In the trusses, all the tension members must be closely examined, also the rods and bottom chords, especially where they are composed of more than one member. All the members in any one panel should have an equal strain, and when they have not, so that one

member is slack and the other tight, the case should be reported at once. The compression members, such as the posts and top chords, should be straight, without a bend or bulge, and all the joints should bear closely against each other. The laterals and counter rods should be tested by shaking them, and they ought never to be allowed to hang loose, but they must not be adjusted with a load upon the bridge, and must be tightened only just enough to get a good bearing, so as not to put heavy strains upon them.

All hangers, by which floor beams or stringers are suspended, must constantly receive close attention. Their bearing around the pins should always be equal and uniform over half the circumference of the latter. If the hangers are made of round or square iron they must be examined with great care in the semicircle where they are bent around the pins, and where flaws or fractures are most likely to occur. It is of the utmost importance that the nuts on the end of such hangers supporting the whole floor of the bridge should never be permitted to become loose. They should have the threads checked to prevent loosening, and a white streak painted across the face of the nut and its bearing will make it easy to detect at once any motion in the nut. This plan may also be applied to bridge pins, and these pins should be examined for signs of rust, wear or bending. The places where stringers are riveted or otherwise fastened to the floor beams, and which are generally not easy of access for inspection, on account of the wooden floor over them, must be thoroughly examined, as here the rivets are most likely to get loose, and the webs and flanges of the beams and stringers are more liable to fail from shearing or crushing than anywhere else. The lateral systems and sway bracing must also be inspected. All the rods should be tight but not overstrained, as the struts are liable to be crippled if too much power is used in adjusting the tension members.

Cast-iron parts of all bridges, more particularly in top chords or joint boxes, must be closely examined, and any cracks or breaks at once reported. A ¼-in. hole drilled at the end of a crack will frequently stop it. Riveted work should frequently be sounded with a hammer to detect loose rivets; and if they cannot be tightened at once they must be marked, and their number and location reported on the monthly report. Bridges in cities near salt water, or over railway tracks, should be very carefully inspected for signs of corrosion. Painted work must be examined for indications of rust underneath. No water must be allowed to collect in the interior of any cast or wrought iron parts; drain holes must be provided and kept open, or the places filled. The wooden floor system must be examined, especially the condition of ties or timbers resting on beams or shelf angles. In addition to the inspection of the superstructures, the masonry of abutments and piers should be examined for signs of settlement, bulging or tilting; foundations looked to, and soundings taken to ascertain if there are signs of scour around piling, piers, or abutments. Pedestal stones should be examined for signs of cracking or crushing, and it should be noted if the masonry requires pointing. It should also be observed if the bridge watchmen and section men keep the bridge seats clean, keep the ballast back from the abutments, and keep grass and rubbish cleared away from wooden structures.

Old timber taken out in repairs and renewals is not necessarily waste or

useless timber, but may be made available in other repair work, and all timber and ironwork should be carefully piled for examination as to its availability and value. In making renewals with creosoted timber, all parts cut for framing, etc., must be saturated with creosoted oil by repeated applications, and then well daubed with hot pitch, this being done as soon as the stick is cut. Every gang using such timber should have a supply of oil and pitch and a 10-gallon pot for heating it. As a rule it is best to have one main yard for timber and piles and to keep only emergency stocks of timber on the divisions. In bridge repair or renewals on double track the tracks may be gantletted along the middle of the structure, thus giving more room for working on the trusses. To prevent accidents, fixed danger signals should be placed at each end of the gantletted track, and no train be allowed to pass over the gantlet unless the pilotman assigned to that duty is on the engine.

Rules for painting were given by Mr. W. G. Berg in his excellent paper on "Painting Iron Railway Bridges," in "Engineering News," New York, June 6, 1895. Railway companies should, as far as possible, undertake the purchase of the raw supplies and the mixing of the paint (by hand or machine), thus being able to insure that the best pigments and oil are used. This is not possible if ready-mixed paints are used. All painting in the field should be done by the railway employees, and not by contract. For new work, use a priming coat of pure, finely ground, dry red lead, toned down with lampblack, and mixed with pure, raw linseed oil, adding as little drier as possible. The finishing coats to be any suitable paint, preferably dark colored, providing the quality of the pigment is not injurious and the linseed oil is pure. If a cheap paint is required, use oxide of iron paint, bought in powder form and toned down with lampblack, in preference to using cheap ready-mixed paints. For repainting old work, first remove all dirt, grease, rust and old scaling or soft paint; if the work is in bad condition, use a red lead primer coat, followed by finishing coats as above; if it is in fair condition, touch up the bare spots with a preliminary extra coat, and then apply the finishing coat. Paint should not be applied when the iron is wet or the weather cold. The Northern Pacific Ry. uses the following: 1st coat, 30 lbs. pure lead to 1 gallon pure boiled linseed oil and 1-3 pint pure turpentine; 2nd coat, 25 lbs. lead, 1 gallon oil, ¼ pint turpentine and not over 12 ounces of lampblack; 3rd coat, 15 lbs dry pigment to 1 gallon of oil. Mr. A. J. Swift, late Chief Engineer of the Delaware & Hudson Ry., deduced a rule for painting iron structures, giving ⅝-gallon of paint per ton of iron for the first coat, and ⅜-gallon for the second coat.

Telegraph Work.

As a rule the telegraph line of a railway is built by the telegraph company in whose district the railway lies, under contract with the railway company, but the supervision and maintenance are done by the railway, its men acting under standard instructions issued by the telegraph company. On the Chicago, St. Paul, Minneapolis & Omaha Ry., the system is divided into eight divisions averaging about 200 miles of pole line. Each division is in exclusive charge of a foreman who is held responsible for taking out all trouble and making repairs. These foremen have other duties, such as taking care of telephones, train-order signals, electric bells and in some

cases electric light plants and Hall automatic signals. Reconstruction has been done by foremen especially appointed for that work, but recently the plan has been introduced of having the division foremen organize crews and do the work on their respective divisions. The latter appears at first to be the more economical, but the experience is that the former plan is the most practicable and satisfactory, and probably most economical. When the different foremen hire separate crews, it takes considerable time to get the men working together to best advantage, and by that time work is generally about completed. On the other hand, a general foreman can have a well organized crew that can work expeditiously all through the season. A single crew also minimizes the amount of clerical work, which in case of a great number of crews is considerable. The telegraph construction or repair gang should be sent out early in the spring, say in March, when plenty of good men can be obtained. They may be carried in a special work train, with boarding and tool cars. In locating the line, care should be taken to avoid sharp curves and sharp changes of grade where possible, and also to locate it so that snow slides, falls of rock, etc., will not be likely to interfere with it. If poles have to be set in frozen ground, an iron jet pipe connected with the engine by hose may be used. In cases where heavy storms prevail from one direction the line should be built on the windward or "opposite" side of the track, so that if the poles are blown down they will fall away from instead of upon the track, as there is great danger to trains from telegraph poles falling or being blown down upon the track, and this is especially the case where tall poles carrying many wires are used. Failure to observe this has caused much trouble. The poles should be thoroughly inspected, and periodically tested by boring (and the condition noted in each case, every pole being numbered); they should also be well braced and guyed when showing signs of weakness, and should be reset when loose or renewed when decayed. The section foremen should know which is the division wire, and repair that first when the wires are down. Wires that are down should be strung on the fence or got out of the way of the track, and prompt report made to the superintendent, so that the linemen or repair gang may be notified at once. The section foremen should understand the imperative necessity of keeping communication open over the wires, and attending promptly to any defect or breakage. When the wire is broken, it should be released from one or two poles on each side of the break by removing the tie wires on the insulators, the broken ends being then united by a screw clamp. A proper joint is made by holding the wires lapping each other in the pliers and taking 5 or 6 short turns of each end round the other wire.

The poles are usually spaced 176 ft. apart, or 30 poles to the mile; sometimes 150 ft. apart, or about 35 to the mile (or 40 on curves). They are of chestnut, red or white cedar, cypress, redwood, spruce, Oregon pine or Norway pine, the latter being usually for very high poles. They should be of the best quality of live green wood, with the butt cut above the ground line of the tree, reasonably straight, thoroughly seasoned, and should be peeled and have the knots trimmed close. If painted or set in the ground when green, dry rot is sure to set in. For single poles, the diameter should be not less than 7 ins., and 20-ft. poles should be about 10 ins. diameter at 6 ft. from the butt. The butt is sometimes charred, or coated with tar to a point above

the ground line, or tarred in a belt at the ground line. The earth should be well tamped around the poles, but not heaped up into a mound at the base, although a small pile of clean gravel or broken stone will keep weeds away and protect the pole from fire. Sometimes the poles are whitewashed. In Europe, the poles are very generally treated with creosote, chloride of zinc and other preservatives, with very satisfactory results, such poles lasting from 25 to 35 years. Creosoted poles are commonly used in English telegraph work, and have been tried in this country, where they have been found in perfect condition, even at the butts, after 12 or 15 years' service. They are better insulators than untreated wooden poles, but are very inflammable, which is one reason for their not being used more extensively for railway telegraph lines in this country. Iron poles are sometimes used, but are dangerous, as they are grounded conductors and likely to cause accidents to the lines and linemen.

The poles should be as low as possible, the minimum headway under the lowest wire being 12 ft., or 22 to 24 ft. at road crossings. Where sleet storms are frequent, double-pole lines may be built, the poles being 6 ft. apart at the bottom and held together at the top by a ½-in. bolt. Two 5½-in. poles may be used instead of one 7-in. pole. They may be braced at intervals, and on curves the outer pole should be anchored. In some cases the two poles are vertical, and connected by the cross arms. Poles on curves should be inclined to resist the pull of the wire, and those on curves and in exposed places where high winds prevail should be supported by braces or by wire guys secured to anchors buried in the ground. The guys are likely to cause a leakage of current. Usually, every fifth pole has a wire lightning conductor, but on account of leakage of current experiments were made in the way of abandoning these. The results were so unsatisfactory that the use of the conductors is still almost universal.

The cross arms are usually of pine or spruce, 3 x 4 ins., painted. Those for four wires or less should be secured by two lag screws, ½ x 6 ins., with washers, while longer arms should be secured by a ⅝-in. bolt and two galvanized iron braces. The arms are set into notches or gains in the poles, these gains being from 1 to 2 ins. deep. The insulator pins are either of wood or steel. The former are usually locust, boiled in paraffin oil, driven into holes in the cross arms and secured by sixpenny galvanized wire nails. The latter are about ½-in. diameter, with a collar resting on the top of the cross arm. The lower part of the pin is secured by a nut under the arm, and the upper part has a wooden sleeve fitting the insulator. The insulators are usually of glass, although in Europe porcelain is generally used. The middle pins are 22 ins. apart, c. to c.; the outer ones, 4 ins. from the end of the arm, and intermediate pins, 16 ins. c. to c.

The wire is usually of copper or No. 6 or No. 8 to No. 10 galvanized iron, and the joints should be soldered. The sag should not be less than 24 ins. between poles, as a short sag puts a heavy strain on the wire, which strain may be calculated by the following formula, in which A = strain in pounds, B = ½ distance between poles, in feet, C = sag, in feet, D = weight of 1 ft. of wire. The proper sag can be determined by sighting over the cross arms, which are 2 ft. apart.

$$A = \frac{B^2}{2C} \times D.$$

The following are the official instructions issued by the Western Union Telegraph Co., in reference to the construction, reconstruction and repair of its lines:

Rules for Telegraph Work.

The minimum depth that poles should be set beneath the surface of the ground is as follows (except where rock is encountered at 2½ ft. or less, in which case it is only necessary to set 25-ft. poles 3½ ft. deep, 30-ft. poles 4 ft., and 35-ft. poles 4½ ft.).

25-ft. poles	4½ ft. deep.	45-ft. poles	6 ft. deep.
30-ft. "	5 " "	50-ft. "	7 " "
35-ft. "	5½ " "	55-ft. "	7 " "
40-ft. "	6 " "	60-ft. "	8 " "

In wet or marshy locations, or where the ground is likely to be softened by heavy rains, or where it is necessary to set poles on slopes, they should be set at a greater depth than above indicated, the object being to set them at such depth that there will be no possibility of their being blown over by any wind.

In building a line, the tops of the poles should be made wedge shape, so that they will completely shed rain or snow. The bottom of the wedge should be 4 ins. above the top of the upper gain. The direction of the wedge must be in a line parallel with the wires and at a right angle to the cross-arms. The slant of poles on curves should be gradual, so that the strain on the poles will be evenly distributed. All sharp curves and angles should be well braced or anchored. Braces are preferable where there is room and suitable timber is available. Braces should be set a uniform distance from the butt of the pole, at least 6 ft. when possible, and the top of the brace should be just below the bottom gain. Where necessary to anchor poles (instead of bracing), the hole for the anchor should be 4 ft. deep and 3 ft. long. Anchors should be so constructed that the top of the anchor will project a sufficient distance above the surface of the ground to admit of properly attaching the guy wire to it. Under no circumstances should the guy wire be fastened to the anchor beneath the surface of the ground. Office poles should be guyed in such a manner as to keep the strain of the wires off the office fixtures and front of building.

Lightning conductors of ordinary line wire will be placed upon every fifth pole on new lines when being constructed, unless otherwise ordered. About 10 ft. of this wire should be formed into a flat coil and placed under the butt end of the pole; the other end of the wire to be stretched up the side of the pole and fastened by 12 or more wire staples, and extended about 3 ins. above the top of the pole on bracket lines, the ground wire should be attached to the pole one-quarter of the way around from the bracket, so that if a second wire is put upon the opposite side, neither of the line wires can touch the ground wire if detached from the brackets. On cross-arm lines, the ground wire should be attached to the pole on the opposite side to the cross arm. Lightning conductors should be attached to all office poles, and when they are placed upon poles already standing, the above directions should be followed as nearly as possible, the coil of wire being placed at least 3 ft. beneath the surface of the ground.

Gains for cross-arms should not exceed ¾-in. in depth in sawed redwood poles, nor 1¼ ins. in round cedar poles that are 6 ins. or less in diameter at the top. Where cross-arm braces are used, the gains should not exceed 1 in. in depth. The distance from the upper side of the top gain to the extreme top of the pole should be 8 ins., and the distance c. to c. between gains must be 2 ft. When additional cross-arms are added to any pole carrying two or more arms, the distance apart must be made to conform to that which may already exist upon such pole. Double cross-arms should be used on all office poles, corners, and at all railway or river crossings, and on all unusually long sections. Cross-arms will be fitted with sufficient steel pins to accommodate only the wires already on the line, or additional wires that are to be immediately constructed. Two bolts will be used in all cross arms.

When building a line, the cross-arms should be faced alternately, first in one direction, and then in the opposite, except when it is necessary to face the cross-arms in a certain direction in order to have the arms pull against the pole where bridle or line guys are used. Cross-arm fixtures should be attached to office buildings with bolts passing through the wall instead of through door or window casing, wherever it is practicable to fasten them in this way. Never use screws for fastening fixtures to buildings, as they are liable to pull out when subjected to a heavy strain.

Wires must be tied on the side of the insulator next to the pole, except on curves or corners, where it may be necessary to place the wire on the opposite side, so that it will draw against the insulator. The full-sized line wires should be carried to the inside of the building from the standard glass and pin insulators on a cross-arm attached to the wall with iron fixtures, in such a manner that the wires will have an upward direction from the insulators to the point where they enter the building, to prevent rain and moisture from following them to the wall. Where the wires run into the building in exposed places, they should be covered with a sloping roof board of sufficient width to perfectly protect them from rain and snow, and should be insulated with rubber tubing where they pass through walls and partitions, using tubing of sufficient length to go entirely through the wall from outside to inside of the building. Where telegraph offices are located in railway stations, or similar long buildings, the wires should enter such offices at the window or other opening nearest the switchboard, and should be so strung that they can be plainly seen and easily inspected at all times.

At railway crossings all the wires must be kept at a height of not less than 25 ft. above the rails, and at public and private highway crossings not less than 18 ft. above the roadway. In the construction, reconstruction and general repairs of lines, all splices must be soldered, except on copper wires, where McIntyre sleeves are used. All connections between copper and iron wires must be soldered.

The wires inside of a building should be insulated on porcelain knobs or wooden cleats, and kept as far apart and as far from the ground as possible. The use of staples for attaching office wires is forbidden. Porcelain insulators and knobs must not be used outside of buildings. Rubber hook insulators must not be used outside of buildings, except in places where they are completely protected from rain, snow or moisture, and where it is impracticable to use the standard glass insulation. All connections in main battery wires must be soldered, and the wires insulated. Permanent terminal ground wires should be composed of No. 8 copper wire, soldered to the main gas or water pipes.

CHAPTER 24.—PERMANENT IMPROVEMENTS AND WORK TRAINS.

One of the striking features of railway management within the past few years has been the amount of work done and the enormous amount of money expended in effecting permanent improvements, undertaken largely for purposes of economy, in order to increase the capacity of the line and to reduce the charges for maintenance and operation. Besides the continual work of improvement which is carried on more or less by every railway, larger works are being undertaken by many roads to improve the railway as a whole, and much of this work is in part under the charge of the maintenance of way department. The question of cost of operation and maintenance were largely overlooked in the location and construction of many lines; while on others a winding and steep location was purposely

adopted to avoid the first cost of heavy works and to enable the road to be opened quickly. On many lines built under these conditions very heavy expenditures have been and are being made in making the works more substantial and in new works and changes to reduce the operating and maintenance expenses. In other cases, the growth of traffic and increase in train loads have made necessary similar alterations, as well as the provision of second or third tracks to increase the capacity. Wherever filling is required, as for building or widening banks, raising grades or filling trestles, the material should, as far as possible, be procured at points where its removal will also benefit the road, as in widening cuts, reducing grades or enlarging ditches. Papers describing work of this character were published in "Engineering News," Jan. 25, 1900. The various improvements may be classified as follows: (1) Reduction of grades and curves; (2) Double tracking or providing additional tracks; (3) Widening embankments and cuts and protecting their slopes; (4) Enlarging and rearranging yards and terminals; (5) Replacing trestles with solid embankments; (6) Replacing timber and old structures with new structures of steel or masonry; (7) Eliminating grade crossings; (8) Constructing new and improved stations; (9) Improving water supply and water stations; (10) Extending the use of signaling, interlocking and the block system. Space does not permit of any extended treatment of this subject.

(1) Changes in Alinement.—Within recent years very many railways have undertaken extensive work of this sort to effect a saving in distance and curvature. The latter is particularly important on high speed passenger lines. The work is practically similar to new construction, but care must be taken to properly connect the old and new work where the two locations cross or meet, and to effect the change in track without interfering with the traffic. New banks may be conveniently and rapidly built by dumping from temporary trestles, with aprons on the sides of the cars and of the trestle so as to throw the material to a distance from the foot. In this way the material will fall towards the sides of the bank and roll back to the center, making it much more solid than if the material is dumped in a single center ridge. On the Boone County (Iowa) cut-off of the Chicago & Northwestern Ry., in 1899, some very large and high banks were built from two trestles 80 ft. apart, with traveling aprons on tracks below the top. Half of each apron was twice as long as the other, so that the banks were built up in the form of eight ridges, making the completed bank very solid. (See No. 3.)

(2) Reducing Grades.—This has also been carried out very extensively, in order to enable heavier trains to be hauled, or to enable standard trains to run through without being divided or assisted by pusher engines. In most cases the alinement has been improved and easier curves introduced at the same time. The work usually combines the cutting down of summits and the raising of sags, and generally involves considerable difficulties in carrying on the work rapidly and economically without undue interference with traffic. The elevation for new grades should be staked out before beginning work if the filling is to be of considerable depth. On one piece of work on the Chicago, Burlington & Quincy Ry., in Illinois, on a stretch of 3 miles with a maximum depression of 13 ft. (in a 6-ft. cut) and a maximum elevation of 12 ft. (on a 33-ft. embankment) a steam shovel

with bucket of 2 cu. yds. was used, loading three trains of 10 flat cars, each train having its own engine and crew. As the material was a wet, heavy clay, and unloaded by side plow, it was necessary to have a fourth engine to help on the cable in unloading. The first cut was made north of the main tracks, the shovel cutting to grade until a depth of 7 ft. below top of tie was reached, that being the extreme depth from which it could dump into cars standing on the main track. The north main track was laid through this cut immediately on its completion, and the shovel started through the second cut, taking it to grade all the way. The third cut completed the work, the south main track being temporarily in the second cut. Thus two through connected tracks were kept in operation at all times; and the delays to traffic were only those due to operating a single track during working hours.

(3) Filling Trestles.—A class of work which is in constant progress on many railways is the filling in of timber trestles with solid banks, providing pipe or masonry culverts for the necessary waterway. The great extent to which timber trestling has been adopted in this country is one of the principal factors in the economy of construction and rapidity of completion which have been characteristic of American railway work, and the use of such temporary structures has been justified by the necessity of keeping the first cost of long lines as low as possible, and by the importance of putting the companies in a position to earn money by carrying freight as soon as possible. Well-built trestles are safe and substantial structures, but all timber structures require frequent attention and repair, and are liable to be destroyed by fire, causing, perhaps, train wrecks and serious interruption to traffic. When once a railway is open, attention should therefore be given to the work of gradually replacing the trestles with solid banks, having culverts or metal bridges for openings, as the banks will be permanent and will, under ordinary circumstances, require practically no repair or attention. This work of filling can almost invariably be done much more quickly and cheaply by work trains after the completion of the road than by the ordinary plant used while the road is under construction. In many cases trestles may be filled with material taken out in widening narrow or wet cuts. Interesting articles on this subject have appeared in "Engineering News," Nov. 28, 1895, Oct. 12, 1899, and Jan. 25, 1900. Aprons may be used to throw the material to each side (as already noted), and in this way as the bank becomes higher and the pressure greater, the earth rolling back towards the center will cause less damage to the structure than when it is dumped close to it in the usual way. The main timber work of course remains in place, but while the work is in progress, the bracing should be removed as far as possible, so that the filling may be homogeneous and any settlement or shifting of the structure will not affect the embankment as a whole. On the Canadian Pacific Ry., the practice is to fill up to the level of the tops of the ties in the autumn, and then to remove the ties, stringers and floor system in the following spring.

Earth or gravel is commonly used, but furnace slag and refuse from coal mines are sometimes available. It is often assumed that the work involves no particular skill or difficulty, beyond keeping the work trains out of the way of traffic, but as a matter of fact each piece of work presents its own difficulties which require special treatment. On soft ground or steep slopes

the work of filling calls for very careful consideration. In extensive work of this kind on the Canadian Pacific Ry., two specially troublesome kinds of soft bottom were met with. In one case, the bottom was practically unfathomable, and swallowed up all of the filling, until the successful expedient was adopted of using light sawdust instead of heavy gravel. In the other case, the soft bottom rested upon a sloping rock bed, down which the bank would slide. In some cases the alinement was changed to avoid the most troublesome and dangerous places (and it is to be noted that it was sometimes found possible to get a better location on firm ground than the original location on treacherous ground), but in many cases the difficulties were steadily fought until overcome. In no case should such work be commenced until careful soundings and investigation have been made as to the depth, slope of hard bottom, etc., and a proper plan then devised in accordance with the conditions to be met. Otherwise the result may be the loss of money, time and material, or the wrecking of a structure and a costly interruption to traffic, as the dumping of material in a swampy bottom or a sinkhole may develop unexpected upheavals in a more or less distant part, which may lead to damage suits or involve the compulsory purchase of real estate.

Not only has the foundation to be considered, but also the trestle itself. Thus in the case of a long structure, especially if the longitudinal bracing is deficient, as is too often the case, it is not safe to fill in from the ends or from one end, as the pressure may result in the injury or collapse of the trestle, but the filling must be carried on uniformly along the length of the trestle, thus maintaining a practically horizontal surface for the bank and preventing the straining of the structure. On such a trestle, care must be taken not to impose severe longitudinal strains by too free a use of the air brakes in getting the gravel trains into position. If the earth or gravel is to be plowed off the cars in the usual way, the strength of the trestle is an important consideration in regard to the resistance to the racking strains, and to the lateral strains if a side plow is used, especially if the material is stiff and the cars are chained to the track. A plow being hauled over a car and suddenly striking a boulder or other obstruction may throw very severe strains upon a trestle. This is more particularly the case where the trestle is on a curve. The strains due to plowing off the material may be considerably reduced by using a "rapid unloader," with a steam winding engine on the front car, as described in Chapter 17. If there are boulders tn the material, an open plank screen, inclined downwards from the edge of the trestle (like an open picket fence) will cause all such large material to fall clear of the trestle bents and form the toe of the bank. Unloading the material by hand shoveling or hand dump-cars is dangerous, there being the constant liability of a man falling from or being knocked off the structure. This is especially the case when dump-cars are used on high trestles, as the floors are usually narrow, and the men likely to stumble, get dizzy or be struck by moving cars. In order to provide against these dangers, two or three systems of dumping cars by compressed air have been introduced and used to some extent. The body of the car is attached to the piston rod of a vertical cylinder, connected by a train pipe and hose couplings with the air reservoir on the engine.

A very effective and economical method of filling where water is obtain-

able under considerable head is that of washing earth into place from the hillside above the trestle, using a 3 or 4-in. water jet from a monitor in the same way as in placer mining, with a head usually of about 200 ft. This method has been employed on the Canadian Pacific Ry. and Northern Pacific Ry. To prevent the water from flowing away too rapidly over the fill, carrying away with it the earth and also washing channels in the side of the embankment, a line of old ties, or a bank 6 to 12 ins. high made of marsh hay faced inside with earth, is placed along the edge of the bank, forming a pool in which the finer material settles, while the water flows over the top. This bank is renewed on the slope as the pool fills. The ties or grass help to sustain the face of the bank, while the grass grows and eventually forms a protecting sod. The water and earth are carried down from the excavation by a flume, the lower end of which is movable, and the flow from the mouth of the flume can be directed to any desired point by means of movable flashboards or planks. There is no obstruction to traffic by work trains, but the progress is usually somewhat slow. The embankments thus made are extremely solid and stable and cost from 1½ to 20 cts. per cu. yd., the general average cost being 5 to 7 cts. per yd. The hydraulic filling is carried up to within 4 ft. of subgrade, and the bank is then finished by means of gravel trains.

(4) Double Tracking.—In widening banks, the ground should be cleared, as in new work, a trench cut to give a footing to the new slope, and the slope of the old bank stripped and stepped or benched so that the finished bank will be homogeneous. If the material is simply dumped over an old and compacted slope, it will be liable to continual sliding. After heavy rains, long cracks will appear at the top and large masses of the new material will break away from the shoulder. The filling can be distributed by side dump cars or a side plow, and leveled by a ballast spreader working on the existing track, as described under "Ballasting." Improvements in alinement and grade very generally go hand in hand with the work of double tracking. The Chicago & Northwestern Ry. in 1896 double tracked its line between Madison and Baraboo, Wis., 37 miles, improving the profile for 60% of the distance. Summits were cut down 6 to 10 ft. and intervening sags correspondingly raised, with the result of materially increasing the hauling capacity of the locomotives. Some heavy curves were also taken out. New banks on the realinement were built by dumping material from temporary trestles, the gravel being plowed off the cars by "rapid unloaders," hauling side or center plows as required. When filled to the level of the trestle, the material for widening was dumped on the shoulder and leveled off by a spreader car. This was described in detail in "Engineering News," June 3, 1897.

(5) Elevation of Tracks.—In many cases where railways were originally built through cities and towns on the street grades, the dangers and inconveniences to street travel and railway service caused by the numerous grade crossings have led to the elevation (or sometimes depression) of the tracks at great expense. This work calls for very careful organization and arrangement in order to keep the cost as low as possible and to avoid accidents or interference with the traffic, which is usually very heavy. In the extensive work of this character at Chicago different methods have been employed. The Chicago & Northwestern Ry. erected the steel bridges on

pile abutments, and built temporary inclines for the work trains bringing the sand filling. The masonry abutments were built afterwards. Sections of one track about ½ mile long, were closed to traffic, switches being put in and telegraph operators established at each end to provide for handling the work trains. The switches were shifted as the work progressed. On the Chicago, Milwaukee & St. Paul Ry., framed trestles were built to carry the tracks across the streets, being raised 3 to 5 ft. from time to time as the filling progressed from adjacent tracks. ("Engineering News," Jan. 11 and Feb. 22, 1900.)

(6) Drainage.—This may include cutting down and draining slopes to prevent landslides, and widening cuts to prevent trouble from snow or from wet, sliding banks, the material thus taken out being applied to advantage in filling trestles. Where cuts give trouble from sliding in wet weather (and where cuts have been made as narrow as possible to save expense in first construction, a very little sliding threatens interference with traffic), it will often be economy to put in a steam shovel and widen the cut to more suitable dimensions, using the material for filling trestles or widening narrow banks. An effort should be made to convince the higher officers of the true economy resulting from such expenditures. Many roads are gradually building new and better culverts, or replacing open culverts having wooden or iron stringers, with cast iron pipe, concrete arched culverts, or short plate girders, having either open floors with ties about 2 ins. apart, or solid floors of old rails or other construction.

(7) Low Grade Tunnel Lines Replacing High Grade Summits.—In several cases railways have been carried over mountain ranges by summit lines, for economy in first cost and for promptness in completing the line for traffic. The increase in train loads and traffic, high cost of operating steep grades, and sometimes difficulties from snow, have in some of these cases led to the construction of a low-grade cut-off piercing the range by a tunnel. The Northern Pacific Ry. crossed the Cascade Range in 1887 by a switchback line 7 miles long with grades of 5.6%, compensated 0.04% per degree, and having tail tracks of 0.2%, 400 to 500 ft. long. The summit elevation was 3,675 ft. The Stampede tunnel line reduced the distance to 3 miles, the grade to 2.2%, and the elevation to 2,827 ft. The Great Northern Ry. crosses the same range by a switchback line 12 miles long, with grades of 3½ and 4%, compensated 0.04%. The summit elevation is 4,055 ft. The tail tracks are level from headblock to frog (100 ft.) and then rise 1% to 5% for 1,000 ft. The tunnel now under construction will reduce the distance to 3½ miles, the grade to 1.74 and 2.2%, and the elevation to 3,350 ft. On the Colorado Midland Ry., the Busk tunnel saves 7 miles in distance, 530 ft. of elevation and 2,000° of curvature, as compared with the summit line (which has no switchbacks). The Zigzag tunnel line on the New York, Ontario & Western Ry., about 1 mile long, replaces a switchback line with four inclines, about 3 miles long, and saves about $30,000 per annum (formerly expended in helping trains over the summit), or more than thrice the interest on the cost of the tunnel. The incline grades were 1.98% for southbound trains, and 1.8% for northbound trains, while on the tunnel line they are 1.25 and 0.75%, respectively.

(8) Minor Improvements.—These may include the filling up of sags and flattening summits (due to settlement of earthwork or bad arrangement

of grades) so as to lessen the trouble from breaking of couplings, caused by the jerks and strains at such places; also the minor but general changes of curvature to insure a better alinement throughout the length of a railway or a division. These improvements may, perhaps, be undertaken on general principles (if the road considers that the result will warrant the outlay) or to enable the road to compete to better advantage with rival routes, this latter having been the cause of the extensive work done for the systematic improvement of the Lake Shore & Michigan Southern Ry.

(9) Resurveys.—Another and more detailed class of work is the entire resurvey of the line to check its maps, profiles, monuments, land boundaries, etc. In many cases the maps and records are incomplete, especially as to changes in location made during construction (which may affect the actual length and position of mile posts), and as to subsequent additions and changes in yards and sidetracks, right of way, etc. This work, as carried out on 600 miles of railway, has been fully described by Mr. Hosea Paul in a pamphlet on "Railway Surveys and Resurveys," and in 1896 Mr. George D. Snyder presented to the American Society of Civil Engineers a paper on "The Resurvey of the Williamsport Division of the Philadelphia & Reading Ry." The subject need not, therefore, be further considered here.

Construction and Work Trains.

The permanent improvements now in progress on a very large number of railways involve the extensive use of construction or work trains, which must be handled promptly and efficiently in order to work them with economy and a minimum interference with regular traffic. Some particulars of the work of these trains have been given in the first part of this chapter, and in Chapter 17.

A work train is usually given train orders authorizing it to occupy a specified portion of the track as an extra, and no other irregular train should then be authorized to pass over that portion of the track without provision for passing the work train. If it is anticipated that a work train may be where it cannot be reached for meeting or passing orders, it may be directed to report for orders at a given time and place. Work trains occupying the main track on a line operated under the block system, must inform the signalman at the entering end of the block (or at both ends on single track), and leave a flagman at the tower. Regular trains will then be stopped, and allowed to proceed with a "caution" card.

Much expense and delay in work done by construction trains is frequently caused by considering these trains as belonging to the very lowest class, and allowing train dispatchers to sidetrack them at any and all times and places, only occupying the main track by special order, after every other train has had right of way. This causes much loss of time in waiting, besides which the steam-shovel or gravel pit crew and the unloading gang are idle when the train is waiting for regular trains which are behind time. This makes the excavating and ballasting very expensive, and might, in many cases, be easily remedied by the dispatcher if made to understand that the work train is an important and expensive item in the maintenance account and should be kept at work to its fullest capacity. Where work is in progress at some distance from a station, a temporary telegraph station or bell-code station may be established at the gravel pit,

and the men in charge of the train kept informed as to train movements. The roadmaster or other officer in charge should see that the trains are unloaded as quickly as possible, the rails properly cleared and ballast or filling leveled off so as not to strike car steps, brake beams, etc., and the train then promptly sent back or got out of the way. It is generally advisable to keep one train of cars in the pit while the other is out on the track.

It is poor economy and bad practice to assign old and worn out locomotives of light power to the work trains, and such engines may cause serious delay to traffic. The engine may be a passenger engine that is somewhat too old for its service, but still in fair condition and not too light. The caboose, supply car, and regular train of service cars should be equipped with air-brake and air-whistle, and whenever going to a considerable distance the train should be qualified to run as a section of a passenger train with perfect safety. Much time is lost by work trains going to and from work, and in passing over the road for any considerable distance during the day, when taking their chances with the other traffic, as is the common practice.

The handling of work trains in connection with steam shovel work, such as in lowering grades and double tracking, where it is necessary to avoid interference with through traffic, depends largely upon the local conditions. In the improvement of the Michigan Division of the Grand Trunk Ry. in 1900, one piece of work included lowering the grade 9 ft. in one place and raising it 9 ft. in another. There were three telegraph offices in about 2½ miles. At each of these was a semaphore, and all work trains were under the protection of those semaphores, regardless of orders. These trains were in no way handled by dispatchers. The operator at the center office instructed the office east and west of him when to block trains. For example, when a train of material left the steam shovel to go east or west, the operator at the center block instructed the operator at the east or west block (whichever way the train was going), and the work train moved in the territory covered by this block, regardless of all trains. It was found that in this way the best service could be obtained from the crews. With three crews, 300 cars of material could be taken from the shovel and unloaded on main line without interfering with the traffic, which averaged in working hours about 8 to 12 trains each way per day.

In the raising of the grade of the New York, New Haven & Hartford Ry. for about 4½ miles at Forest Hills, near Boston, Mass., the earthwork filling was done from the temporary main line double track trestle between the masonry walls. The filling material was obtained from a gravel pit 13 miles distant, and the gravel train service was very carefully organized. Small dump cars were at first tried, but gave much trouble by getting derailed, and flat cars used were found to be unsatisfactory by reason of the time occupied in unloading them. Each gravel train was therefore made up of 20 Pratt dump cars of 25 cu. yds. capacity each, or 500 cu. yds. per train, hauled by a powerful mogul engine. There were about 1,000,000 cu. yds. of filling altogether, and the work went on at the rate of about 13,000 cu. yds. per week. One shovel was usually employed loading one train while another was on the work, but another shovel was put in service if the first could not keep the trains supplied. This work went on night and

day. With two shovels at work, 3,500 cu. yds. (or seven train loads) could be dumped in 24 hours. The unloading was attended to by groups of men on the track, who also attended to the ballasting, lining, surfacing and general work on the track. In some of the improvement work done on the Chicago, Burlington & Quincy Ry. in 1899, the average haul from borrow pit was two miles, and the contractors used a 1¾-yd. steam shovel and two switch engines, each handling a train of 16 standard gage, 5-yd., side-dump cars. The work was prosecuted night and day, in two shifts of ten hours each. A comparison of the efficiency of flat cars and cable with the side-dump cars was greatly in favor of the latter. Under very favorable circumstances a train of 16 loaded cars was dumped and righted, ready to return to the shovel, in 2 minutes; and the average actual working time was about 6 minutes, or one-third the average for flat cars and plow. The train load was 65 yds. in each case. A large amount of information relative to widening cuts and banks, operating gravel trains, etc., is given in Mr. Hermann's book on "Steam Shovels and Steam Shovel Work."

If a work train engine is only required to take the men to and from their work, this engine should attend to the distribution of material for the sections, which frequently require such assistance, and if it cannot be so employed it should be turned over to the transportation department from the time of delivering the men at their work to the time of taking them home in the evening. When it is considered that this engine costs about $25 per day, including the crew, it will be readily seen that with a force of laborers costing $25 a day, it increases the cost of every day's labor performed 100%. Hence the practice of running a work train with a small force of laborers is an expensive luxury, and any work train gang composed of less than 50 laborers will make the average rate of each day's labor higher than any contractor would figure on doing work. Of course, there is always work on the railway that cannot be done by contract, and is only possible to reach by the use of an engine; but the force of laborers should bear such a proportion to the cost of the engine that the cost of each day's labor is within reasonable limits. In many cases the engine can be profitably employed in unloading rails, stringing new rails, distributing ties, moving switches, etc.

The foreman of the construction gang should act as conductor of the train and share the responsibility for the safety of the train with the engineman. A conductor who has nothing to do with the work of the train should not be employed, there being too many opportunities for him to sleep in the caboose, and he will consequently antagonize the foreman, who is particularly interested in and held responsible for a fair day's work. By the foreman acting as conductor, he gets a knowledge of the trains that he would not otherwise have, which enables him to arrange his work to better advantage, and especially smaller items of work (which consume so much of the train's time), so that it can be done between the time of certain trains. This conductor must be an expert foreman, qualified in all branches of track work. He should be provided with an assistant foreman, thus enabling him to give more time to the trains than otherwise would be possible, and, if his force is large enough to require it, he should also be furnished with a timekeeper. He is responsible for seeing that the cars are in good running order, and must make reports of all track material

delivered, and of all delays experienced through not receiving orders promptly. On the New York Central Ry., the conductor is under the immediate direction of the supervisor, and acts as foreman of the gang, the assistant foreman taking charge when the conductor leaves with the train. The trains are usually required to be clear of the main track between 5 or 6 a. m. and 7 p. m., and to be sidetracked for the night at a telegraph station.

The conductor and dispatcher should work in harmony, the former notifying the dispatcher as to the location of his work, the time it will probably require, and his movements when the work is finished, while the dispatcher should inform the conductor as to expected movements of trains affecting him, especially of expected extras, so that he can report at a telegraph station in time for orders. It too often happens that the work train is tied up by signals put on regular trains to enable the dispatcher to run other trains which could otherwise be run as extras. The limits of the work train should be as short as possible, as the dispatcher can handle it better, and where the track is crooked and traffic is heavy the work trains should not be allowed to work under flag on the time of freight trains. A work train conductor working on limits should not run past telegraph stations on the way to sidings without ascertaining the times of regular trains and whether the dispatcher can assist in any way. On the other hand, dispatchers should be held strictly accountable for delays to work trains.

On the Lehigh Valley Ry., the work train crews are in the roadway department, and each crew consists of an engineman, fireman and three brakemen. These men are selected with great care and are considered experts, as there is no more important train than the work train, being in the way of all extra trains, and as the traffic is very great the best men are necessary for the most effective working. There is also a man who acts as conductor and foreman, being selected from the roadway force, and having been raised on the division on which he works. He is qualified to do all kinds of construction and repair work in the roadway department, and is required to pass the regular conductor's examination. There is also an assistant foreman, who is a first-class man, and when the force of men numbers more than 40 a timekeeper is assigned to the gang. The work formerly done by floating gangs is now done by the work train gang, which is an improvement, as the material for the floating gang was handled by the work train, and this train was often put to a disadvantage in taking that gang to and from work. Work train extras are assigned working limits by special telegraphic orders, in accordance with the standard code. They are required to clear first and second class trains by 10 minutes. Most of the freight trains are run as extras, and in such cases, the work train works until overtaken, being protected by a flagman. When schedule trains are late, the work extra is given time on the delayed train, the same as any other extra. The work train gang may assist the track gangs at times, as in reballasting when waiting between trains. Ties, rails, etc., should be unloaded at suitable points and where needed, so as to avoid rehandling on the right of way as far as possible. On the Pennsylvania Ry., work trains are assigned to all main line supervisors and to branch line supervisors where the traffic is heavy enough to warrant it. The work

trains are run as extras, and on single track they are handled by the dispatchers so as to give them every opportunity to work without causing delay to their own movements or to regular trains. Working limits are given wherever possible.

On the Southern Ry., work or gravel trains are run as extras under special orders, and the practice is to assign them working limits each day between certain mile posts, and for them to keep out of the way of all regular trains. When any special work is going on they are allowed to work close up to the limits, and are given special orders against every train up to the time of arriving, if the trains are behind time, but are required to be clear of passenger trains' time and to keep out of the way until the passenger train has passed. Where there is specially important work being done, a telegraph office is opened and all trains are required to come to a stop before entering the limits assigned to the work train, until given an order to proceed. These orders are rarely given against first-class passenger trains.

CHAPTER 25.—HANDLING AND CLEARING SNOW.

One of the annual difficulties encountered is that of dealing with snow, and keeping the road open during the winter. If a road is carried on an embankment, even a low one, the snow will drift up on the windward side until it is level with the track, and will then blow over and form a drift on the other side, so that it is not difficult to keep the track clear. For this reason, even prairie lines should not be built on the surface level, but should be raised on embankments. Shallow cuts will soon fill if the wind is blowing across them, unless snow fences are built (see Chapter 8). In deep cuts there will be greater trouble in getting rid of the snow, and all cuts may be made less troublesome by widening them and flattening the slopes. In sidehill work the drifts against the bank are likely to be dangerous, especially if the toe is about even with the outer rail, as the side pressure on the plow is likely to cause derailment. Drifts containing earth or sand are very heavy and dangerous. Shallow drifts across the rails, which cause trains to lose time, or necessitate reducing the number of cars, may be successfully dealt with by pilot plows and flangers on the engines, or on specially equipped cars attached to the trains.

Steady falls of light soft snow at a mild temperature are the easiest to deal with if the road has proper equipment, but if the temperature is very low the snow may settle and freeze into a mass, or if the wind is high it may be packed very hard in the drifts. Hard dry snow, whether drifting or packed, is apt to be troublesome by filling up against the rail heads, increasing the liability of the engine wheels to slip and even causing derailment unless flangers are promptly used. The same trouble, but of greater extent, results from partial thaw followed by freezing, which causes the formation of solid ice on the roadbed. The worst drifts are formed by heavy falls of dry, hard snow which will form drifts in every place affording a lee side. Where the wind blows through a cut instead of across it the snow will not drift, and in fact a change of wind may clear

a cut in which the snow is not packed hard. The weight of snow varies from 12 to 25 lbs. per cu. ft., according to its condition, while the heavy masses in snow slides sometimes weigh as much as 45 lbs. The weight in Canada has been given as follows: Freshly fallen snow, 14¼ lbs. per cu. ft.; 24 hours after falling, 8° F., 21¼ lbs.; 72 hours, 30° F., 28.7; but after high winds, which pack it hard, it will weigh about 30 lbs. per cu. ft. If the snow in drifts 3 to 7 ft. deep has been partly thawed and refrozen and become very hard packed, the plows may ride upon it and be derailed.

Snowsheds are sometimes built in open flat country, but mainly on sidehill lines and to cover deep cuts on mountain divisions, at places where deep drifts occur. They are usually heavy log structures, sometimes with rock-filled cribbing on the uphill side, earth being filled in behind the cribbing to a level with the roof of the shed so as to form an even slope from the hillside to the outer edge of the shed roof. The bents are 5 to 10 ft. apart, and framed bents of triangular section are often used for the outer

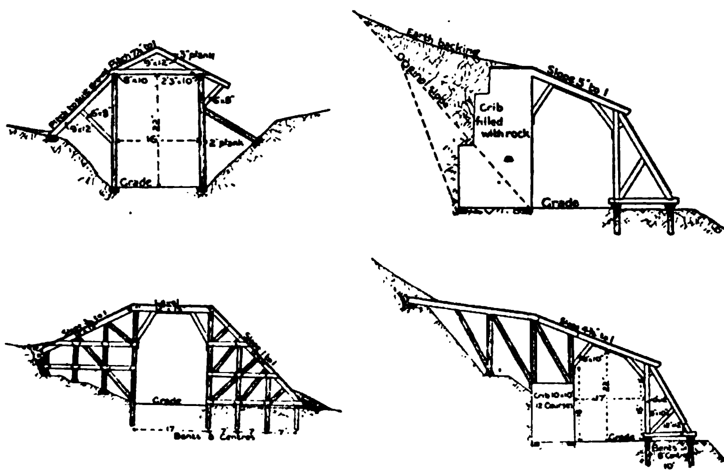


Fig. 219.—Snow Sheds; Canadian Pacific Ry.

or downhill side. Planking is spiked to the batter posts of these bents, a narrow opening for light and air being left along the upper part, under the overhang of the roof. The timbers are usually 8 × 10 to 12 × 12 ins., with 3-in. and 4-in. planking. Some forms of snowsheds used on the Canadian Pacific Ry. are shown in Fig. 219. On this road an open air line is laid outside the snowsheds for use in summer. On hillsides where snowslides occur, glance and split fences are sometimes used to guide the snow into gullies and to break up the slide. The latter are V-shaped, with a sharp angle and a strongly braced and anchored crib at the point. They are used to protect ventilating openings in the sheds, as in heavy weather the smoke escapes slowly, and the shorter each shed is the better. The sheds must be carefully watched and patrolled, as there is great danger from fire, which, if once well started, is very hard to fight. On the Central Pacific Ry., fire trains, equipped with tanks, fire pumps, hose, etc., are kept in readiness

at sidings in the sheds, while some of the large sheds on the Canadian Pacific Ry. have pipe lines, with 200-ft. coils of hose at hydrant nozzles 400 ft. apart.

In fighting snow there are two methods to be followed. The first is defensive, consisting in the erection of snow fences and sheds, and the use of pilot or engine plows or plows hauled by the trains, so as to keep the snow from covering the track to such a depth as to interfere with the traffic. The second is aggressive, and consists in the use of breaking plows and armies of shovelers to clear deep drifts and heavy falls which threaten to blockade or have blockaded the road. In a heavy storm or a succession of storms, the main thing is to keep on breaking up the drifts by snow plows, so that they do not have time to pack and become so hard as to require shoveling, and the work of the breaking plow must be supplemented by the wing plow and flanger to widen the cuts and clear the rails.

The shoveling of snow by hand is slow and laborious work, especially in heavy drifts and with snow still falling or fierce winds blowing. Such work is often attended with danger, and the officers in charge should see that the laborers sent out are warmly clad, and that provisions and hot coffee are provided. In shoveling from deep cuts, the work must be done in benches, the vertical height of which is the height to which the men can shovel the snow without too much exertion. With shoveling in heavy work there is sometimes difficulty in getting rid of the material, and it has to be carried out on work trains, and dumped over trestles, etc. In one case on the Canadian Pacific Ry., after several small structures had been filled the snow trains had to be run considerable distances, entailing great loss of time and constant trouble in backing up over badly flanged track, due to the almost continuous snowfall and drifts in that neighborhood. These difficulties were avoided the next year by the use of the rotary plow and a small gang of shovelers. The compressed snow on the slope was shoveled onto the track to a width covered by the scoop of the rotary and the wings of the wing-plow, and was thus thrown clear of the track, and a good flangeway left. In heavy level snowfalls of over 12 ins., the rotary plow was used, but with less than that the ordinary wing-plow was used, as it could be run faster, and time was of first importance, besides which the wing-plow, of course, cost considerably less in operation. Cuts widened in the way noted above are less liable to fill up again very quickly. Some roads slope the snow cut back for 30 or 50 ft., and the wider the cut the longer it will stay open.

A deep snow cut with vertical sides, as left by the plow, is liable to fill very quickly, and it is wise to break down the sides, shoveling the loose snow into the cut, and then run a wing plow through at high speed to fling the snow to a distance. If the snow in deep drifts is hard, it is well to cut trenches across it, either large trenches, 30 ft. long and 10 ft. wide, and about 30 ft. apart, or short ones with two men to each trench, the trenches being just as long as the men can work, and 15 ft. apart. This can be done by the regular section gangs as well as the snow shoveling gangs, and enables a locomotive with engine or breaking plow to clear the drift. When men are engaged on this sort of work, or in a narrow snow cut with vertical sides, a man should be posted on top of the cut to watch out for and give warning of the approach of trains or plows.

The section men and yard men must look to the clearing of snow from yards, switches, frogs, crossings, guard rails, etc. Yards should have plenty of good clean ballast, and be kept well drained, so that in case of a cold snap following a thaw there will be less liability of thawed snow freezing up the switches, etc. The trenches in which switch connecting rods work should be kept open to prevent the accumulation of water which, by freezing, might prevent the operation of the switch. Salt should be used in clearing snow and ice from switches and frogs, and light drifting snow frequently swept out, the slide plates being also frequently oiled as the salt water will rust the iron and make the switch rails hard to move. Where many snowstorms occur during the winter it is a good plan to put up posts near the switches in yards, with a broom and shovel hung on each ready for use by trainmen or others.

The use of plows should be commenced as soon as a storm begins, pilot plows being used first to clear light drifts. For heavy work, the snow is first broken up by a plow driven into it by two or more engines, and when a passage has been made, the cut is widened by running a plow through it with wings extended. These wings are hinged to each side of the plow, and can extend about 3 ft., their spread being controlled by a man in the "lookout" in accordance with whistle signals from the leading engine. They are, of course, closed in to clear bridges, tunnels, etc. On lines with two or more tracks, an engine with a wedge-shaped, square-nosed plow in front and a wing plow behind may be run on one track, throwing a bank of snow over towards the next track. Following this on the other track is an engine with a side-delivery plow in front and a wing plow behind, with the wing on the outer side of the track extended. This will not only clear its own track but clear off the snow thrown out by the wing of the first wing plow.

Flangers and Flanging Cars.—An important auxiliary to the snow plow is the flanger, which clears the snow and ice away from the rail heads, especially on the inner side, so as to leave an ample flangeway (usually about 5 ins. wide) for the wheels. This device is usually mounted on the snow plow, but sometimes it is fitted to a special flanging car, and operated by hand levers or air cylinders, it being necessarily raised at frogs, switches and crossings, and at road crossings where the planks have not been removed. The Nevens flanger is fitted to a car, and consists of a double-bladed scraper, set diagonally across the track at an angle of about 75° and resting on the rails. The car can be run in either direction. Each blade consists of a steel knife for cutting the snow and ice, and a mold board so curved as to throw the snow well away from the track. The blades cut even with the tops of the rails, 16 ins. wider than the gage, and also cut a groove 2½ ins. deep and 15 ins. wide inside each rail. The mold boards and knives consist of two parts set end to end with a middle vertical joint, and provided with a connecting sleeve and spring which allow the parts to close together in case the scraper strikes an obstruction. The flanger is raised or lowered by levers, and the car can be run at 30 to 35 miles per hour. One form of flanger for pilot plows is shown in Fig. 220 On the Northern Pacific Ry., flangers are secured to the pilot and work in combination with a shallow snow plow wing, the flanging knives being secured at front or point of pilot and lifting at rear end only.

The Priest flanger, which is used on a number of roads, is a flanger only, and not designed for heavy drifts. It goes behind the pilot, supported on the equalizing bars, the cutting thrust being borne by the engine truck box. The object in carrying the cutter bar on the equalizers is to obtain an even depth of cut, which is done by using slotted lifters, so that the cutter bar partakes of none of the vertical motion of the engine on its springs. This feature is designed to give an even depth of cut, however rough the track may be. The lateral motion of the bar, on account of its being but little in advance of the axle, is not much greater than that of the wheels, so that good work can be done on sharp curves as well as on tangents, and without touching the rail. The cutters may be set to within ¾-in. above the rail and 1¼ ins. clear of each side of the rail head. Experience has shown that the clearance on the sides could be increased to 3 ins. and still allow good work, the snow and ice being unable to remain on top of and against the side of the rail after the removal of the backing which supports it. With this clearance, torpedoes fastened to the rail remain undisturbed by the flangers. This machine cuts a swath 12 ins. wide inside and outside of rail, 1¾ ins. deep inside and ½-in. deep outside. The knives only are liable to injury, all reinforcing bars being carried sufficiently high to clear everything. The knives require simply the manipulation of one bolt in removing them. The flanger is lifted by means of air.

A handy device for dealing with moderate depths of snow on side or main tracks is a flat car fitted with a nose plow and flangers, the car being well weighted, especially at the ends, by car wheels or stone. The Michigan Central Ry. has a car of this kind mounted on rigid-center trucks. The plow is of wood and has a vertical nose and sides, the sides being 8 ft. 4 ins. long and 5 ft. 6½ ins. high. It is hung upon the end of a beam 12 × 14 ins. (above the floor), hinged at the rear end of the car, and raised by two vertical brake cylinders mounted near the front end of the car. The flanger is attached to the heel of the plow. A somewhat similar car on the Pennsylvania Lines has a fixed nose 7 ft. 2 ins. wide at the heel, 5 ft. long on the center line, with an angle of about 80°. It is faced with iron like a pilot plow, the height of the nose being 2 ft. 4 ins. Between the trucks is hung the flanger, which resembles the plow but has an angle of 60°. This is hung on the end of two 10 × 5-in. timbers 14 ft. 8 ins. long, set on edge, which form a V, the nose of which is inside the point of the flanger, while the ends butt against the transom in front of the rear truck and are hinged by straps to the intermediate sills. The flanger can be raised by a 10-in. inverted air cylinder, the piston rod being connected by a rod with the flanger, which moves vertically in guides.

Pilot and Engine Plows.—The use of pilot plows, or snow plows bolted to the engine pilot, is common on most railways which have to deal with moderate or heavy snowfalls, as they serve to keep the track from getting blocked with snow, except in case of very heavy storms or drifts, and enable the train to make better time by clearing the track of light snow. In general these are curved plates rigidly bolted to or in front of the pilot, but Fig. 220 shows an adjustable plow, operated by air from the brake reservoir, which has been used on the Grand Rapids & Indiana Ry. for some years. Four flat bars (A) are bolted to the bumper beam, and carried down to within 3 ins. of the rail level, being then bent back and inclined upward

to have the rear ends attached to the cylinder casting. The inclined part of each bar is stiffened by a tee iron (B). The plow (C) is of the usual form, with overhanging nose and curved wings, 18½ ins. above the rail. The sides and bottom are stiffened by angle irons. On each side of the bottom is bolted an ice-cutter or flanger (D), consisting of a ½-in. steel plate with notched edges. When in position for work, this ice cutter is 3½ ins. below the top of the rail. On the bumper beam are bearings for a 3-in. shaft (E), carrying two arms (F) connected by a rod (G),. To this rod are hung two links (H), by which the heel of the plow is lifted, sliding vertically on the bars (A); also a diagonal rod (J) which lifts the nose of the plow, and is adjusted by means of a turnbuckle. An upright rocker arm (K) has a connecting rod (L) to the piston rod (M) of an air cylinder

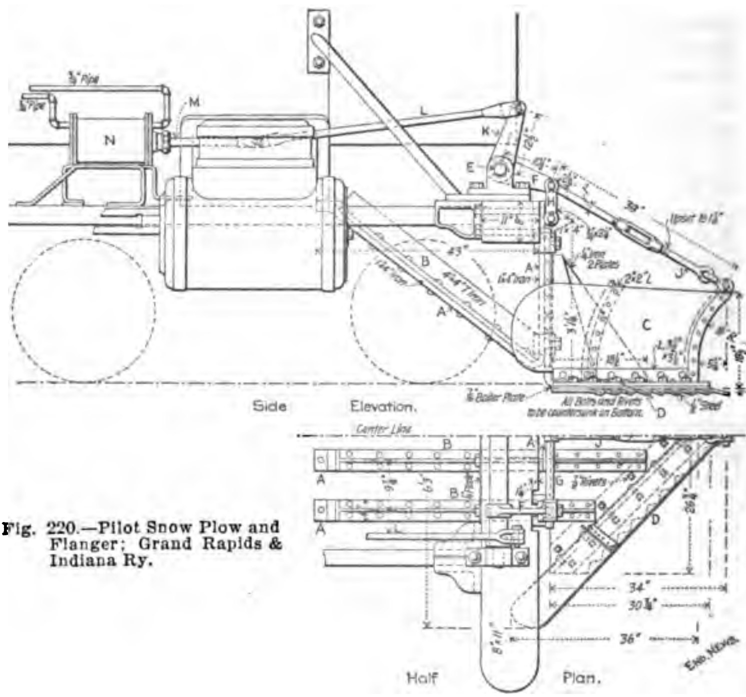


Fig. 220.—Pilot Snow Plow and Flanger; Grand Rapids & Indiana Ry.

(N) placed behind the steam chest. The Chicago & Northwestern Ry. has a somewhat similar plow, but with a flanger pivoted to the outer side of each face of the plow, the flangers being raised by an inverted air cylinder behind the plow. Slots allow the flangers to move ahead in rounding curves, the pressure of the snow bringing them back into normal position.

The larger engine plows are usually of iron, bolted to a special frame which takes the place of the pilot, the plow extending above the top of the boiler and being braced to the frame and smokebox. On the Northern Pacific Ry., snowdrifts up to 4 ft. deep are handled with pilot plows, unless too hard, in which case channels are cut across the track. The engine plows are of the wedge type, of two designs; one has central deflecting

wings, which throw the snow to each side of the track, and the other has a single wing placed diagonally on the wedge portion of the plow and throwing the snow to one side of the track only. This wing is adjustable and used on either side at will. On double track, the single-wing plow is found to be most useful. Engine plows of this kind have been used for drifts even up to 15 ft. deep, the drifts having first been cut by cross trenches. Wire brushes should be attached to engine pilots and behind all flanges so as to clean the rail head.

Breaking Plows.—The ordinary form of breaking or driving plow resembles a large box car with an inclined front end, the plow being propelled by locomotives in the rear. If the plow is run at high speed into a drift it has to stand very severe racking and wrenching strains, and not unfrequently leaves the track. This leads to continual delay in digging out and replacing the plow. If the plow and engines strike a heavy drift the sudden shock is likely to derail both plow and engines, or to shift the tender tanks, or the plow may run up into the snowdrift. Drifts that have been in place for several days should not be attacked until soundings or some investigations have been made, as alternate thaws and freezing may

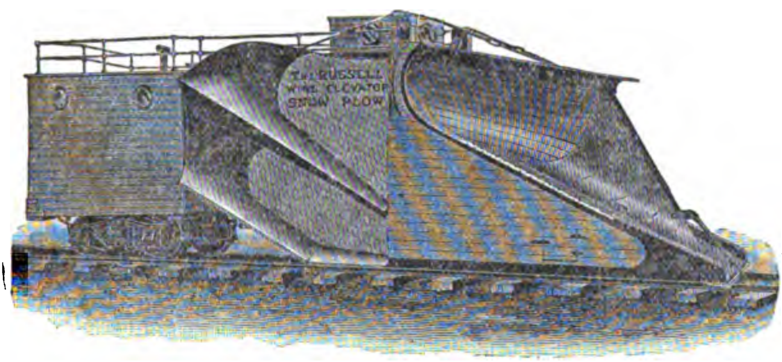


Fig. 221.—The Russell Snow Plow, with Wings.

have caused dangerous pockets of hard ice. The plow will only drive a certain distance into the drift, and must then be dug out to enable the engines to haul it back for another run, and sometimes one or more of the engines has also to be dug out. The dimensions of any plow in cross section should be such as to leave a clearance of 3 to 5 ins. above the rails and 5½ ins. between the plow and fixed structures, such as bridge abutments, tunnel walls, freight platforms, etc. The plows of the New York Central Ry. are 10 ft. 1 in. wide, and 12 ft. 2 ins. high from the ties, the overhanging nose being 9 ft. above the ties. Sometimes the face of the plow is square to the track, but more commonly it is wedge-shaped in plan.

The Russell snow plow, shown in Fig. 221, is extensively used. It has very heavy framing and lateral bracing, and is mounted on two four-wheel trucks with roller side bearings. For single track, it has a central nose dividing the inclined plane of the face; for double track, it has a vertical nose at one side, so as to discharge the snow at the side only. The latter plow

may also be used for sidehill work. The large plows have on each side an elevator wing, 9 × 11 ft., for use in deep drifts, the wings being forced out so as to widen the cut, and having curved channels by which the snow is delivered above the machine. These, with a slight tapering of the sides back from the front, prevent the snow from wedging or binding against the side of the plow. The wings are operated by gearing by means of hand wheels in the car. The pushing bar is formed of two oak timbers bolted together, and the front end is let into the oak timber which forms the backbone of the inclined face of the plow, so that the propelling power is applied right at the nose of the plow and not at its rear. This greatly reduces the danger of derailment, and the plow is in practice run up to its work in drifts 5 to 15 ft. deep, at speeds of 25 to 35 miles per hour. The rear end of this timber is fitted with a heavy coupler head having slots for close coupling to engines of different heights. The timber is not a fixed part of the framing, but has a lateral movement, allowing it a certain amount of play on curves. A coupling bar extends through the face, by means of which the plow can be hauled. The horizontal edge has a sharp steel cutting edge; about 5 ft. back from the edge begins the share, with curved flaring sides to throw off the snow. The sharp cutting edges of the front and sides enable the plow to get into and under the snow, wedging it up and lifting and loosening it before it reaches the share where the side pressure begins. This again tends to reduce any liability to derailment. The front end is covered with a ⅛-in. steel plate, and the double track plow has on the side opposite the run of the share a ⅜-in. steel plate extending the full height of the machine, its front edge forming the vertical cutting edge in advance of the share. In working, a man rides in the cab or outlook and signals the engineman of the pushing engine by a bell cord.

A Russell plow has successfully attacked hard packed snow 6 to 8 ft. deep, using two engines with a run of about ¼ mile, and having a speed of about 30 miles per hour. With one engine it will handle 6 or 7 ft. of snow and go through 4 or 5 ft. of snow for half a mile without stopping. With two engines it will handle 7 to 11 ft. of snow and go through 8 or 9 ft. for ⅛ mile without stopping. One of these plows, weighing 32 tons, and being 40 ft. long and 11 ft. 8 ins. high, has been used on the New York Central Ry., usually with two mogul engines having cylinders 19 × 26 ins., but sometimes with three lighter engines. Drifts 3 to 9 ft. deep and 200 ft. long, and up to 10 and 15 ft. deep, 300 ft. long, were disposed of, and also a drift of 2,200 ft. long and 3 to 10 ft. deep. The speed was about 30 miles per hour in running at the drifts. After the first cut is opened, the plow is run through with extended wings to widen the cuts and make a slope instead of a vertical wall.

Machine Snow Plows.—The first machine plow was the Leslie rotary plow, which was introduced in 1885, and has been adopted on several railways. It is a large car mounted on four-wheel trucks and containing an engine and boiler, with gearing to drive a wheel 11½ ft. diameter which revolves in a vertical plane transverse to the track. The wheel revolves in a circular shell or drum, in front of which is a rectangular housing 12 ft. wide which trims the sides and bottom of the cut, leaving only 3 ins. of dead surface on each side to be sheared off by the hood. The wheel has 12

radial conical tubes, with a slot in the face of each fitted with a blade 4½ ft. long. The snow falls through the tubes to the back of the wheel, which acts as a powerful fan, discharging the snow through a movable chute in the top of the drum. The ice cutters are capable of cutting ice 2 or 3 ins. thick, and the flangers remove the snow and ice between the rails and deliver it clear of the track. These devices are attached to balanced arms on sleeves on an axle of the front truck, the arms being controlled by an air cylinder operated from the pilot house. The cutters and flangers are each held in place by a shearing bolt, which will break if an obstruction is struck, thus allowing the blades to swing up. The machine is about 30 ft. long, weighing 55 to 85 tons, and the largest size has engine cylinders 18 x 26 ins. A tender carries 4,000 gallons of water and 5 tons of coal, and behind this are the pusher engines.

The Jull or "cyclone" plow is mounted on a six-wheel leading truck, and a four-wheel trailing truck, and carries the machinery for driving a huge cone. This cone has its apex at the front lower corner of an enclosing frame or housing, while the center of the base is at the opposite back upper corner. The cone is built of ½-in. steel plate, and is about 7 ft. 8 ins. long, 1 ft. diameter at the apex and 7½ ft. at the base, having riveted upon it four spiral curved cutting blades, making about ¾ of a revolution in the length of the cone, and varying in height from 16 ins. at the axis to 24 ins. at the base. The blades are made of two thicknesses of ⅜-in. steel plate, pressed to shape in dies. At the front they are nearly straight, but towards the base their curve increases gradually. They are cut away at the base, however, for a width of 24 ins. on the cone, to allow the snow to escape freely. The housing of the cone is 10 ft. 4 ins. wide, 9 ft. 4 ins. long, and about 9 ft. deep, the bottom being 3½ ins. above the rail head. The edge of this cuts into and loosens the snow. The cone is revolved at high speed, and the blades carry the snow to the back of the cone, where it is thrown off by centrifugal force through one or other of the adjustable openings, falling at a distance of 40 to 60 ft. from the track. The engine has cylinders 18 x 24 ins., driving the cone shaft by bevel gearing, the ordinary speed being 250 revolutions of the engine and 300 of the cone, per minute. The flanger between the trucks is a V of ½-in. steel plates, 18 ins. deep, with a width of 7 ft. over the broad part. It is mounted on a parallel motion, and is so adjusted that it will swing back and up if it strikes an obstruction. It slides on top of the rail and is raised or lowered by a steam cylinder controlled by a lever in the cab. The entire machine is about 42 ft. long, and weighs 65 tons. A tender is coupled to the rear and behind this are the pusher locomotives.

The introduction of machine snow plows has rendered the work of keeping the lines open and of opening blockaded lines very much easier than when only breaking plows and hand shoveling were available, but there are limits to the use of these machines. The Colorado Midland Ry. has had considerable experience in dealing with snow, and has tried both forms of machine plows, with results which are noted below, being taken from "Engineering News," of Aug. 23, 1900. The snow is sometimes 30 ft. deep, and there are grades of 3% with sharp curves on the part of the line where the greatest trouble is experienced. The preference is for the rotary machine, though either one will cut its way through newly fallen snow drifts, 3 ft. to

6 ft. deep, at 8 to 10 miles an hour, and through snow 10 to 11 ft. deep at 5 to 6 miles an hour. Experience has shown that the "rotary" plow delivers the snow in a clean stream from the outlet over the wheel, and throws it 40 ft. to 200 ft. from the track, according to the velocity of the wheel. The "cyclone" plows throw the snow in promiscuous ways, some going to the right, some to the left, and some falling directly on top of the machine. These plows, however, were old ones, formerly used on prairie roads.

In the very hard snow encountered during the winter of 1898-99, it was impossible to advance 1,000 ft. in the snow in an hour, even after channels 4 to 6 ft. long at right angles with the track had been dug from the surface down to the rails, leaving from 7 to 10 ft. of snow between the channels. This was the case even when the rotary plow was handled with five engines. The object in using so many engines was to push the plow into the snow so as to keep it moving slowly all the time and so prevent stalling the train or choking the plow. The snow was channeled so that there might be no danger of crushing the plow by pushing it against a solid mass of snow with five powerful engines.

In some places the plow encountered snow 34 ft. deep, and even if it had been possible to push the plow into such a depth of snow it could only tunnel a few feet before the outlet over the wheel would be closed and it would be impossible for the wheel to throw the snow away. Under such circumstances, the only practicable method was to place lines of men above each other on the slopes of the cut, one line of men throwing the snow up to the line above, until it was raised to a height varying from 40 to 60 ft., and finally disposed of, leaving not more than 12 ft. of snow in the bottom of the cut. Holes were drilled into this bench of snow and giant powder exploded to shatter the frozen bank, after which the men were stationed on the bench of snow immediately in front of the plow to drag the snow down with shovels and throw it in the bottom of the cut in blocks from 1 cu. ft. to 2 cu. yds. in size. After breaking this snow down, the plow would run into the loose snow, throw it up on the bench excavated on the slope of the cut for men to stand on, and the men would shovel it one to the other again until it could be disposed of over the top of the cut. Each time the plow would run into the shattered snow it would remove that snow and force itself from 5 to 10 ft. into the undisturbed mass of snow. Progress was necessarily exceedingly slow in such work.

The "cyclone" plows were of little service in this class of work, as the snow fell back around the plow, settling between it and the walls of snow and sealing the plow into the cut. The "rotary," on the contrary, would deliver a clean stream of snow, nearly as large as a flour barrel, very much as a stream of water is delivered from a fire hose. As long as the wheel could be turned at its highest velocity the snow would be delivered so far up on the sides of the cut that very little of it would roll down around the plow. The "cyclone" plow took much more power to force it into deep and hard snow.

It was found almost impossible successfully to operate a plow unless equipped with very strong and substantial ice cutters in front of the forward trucks, so as to remove any ice which might have formed on the rail, and as it is very necessary to remove entirely the snow and ice from the rails in order to give the engines a good grip on the rails, it is necessary to

have the plow as close to the rail as possible. One of the "cyclone" plows stood 4 to 5 ins. above the rail. This left so much snow on top of the rail for the flanger to move that it would be thrown up against the banks, and as soon as the flanger had passed it would roll back on to the rails, leaving a very bad rail, often covered by 6 to 8 ins. of snow. This would cause the engines to slip badly, and ice would form to such an extent that often the plow train could not proceed more than a train length without stopping while the track was flanged by hand, so as to give the engines a footing and enable them to do the work.

CHAPTER 26.—WRECKING TRAINS AND OPERATIONS.

The exigencies of railway operation, the impossibility of avoiding accidents, and the necessity of removing train wrecks and repairing washouts, etc., with the least possible delay, so as to keep the road open for traffic, render it necessary for every railway to keep in readiness for immediate use "wrecking trains" equipped with cranes, tools and appliances for clearing the track or building temporary structures. The wrecking train, therefore, is a highly important part of the operating plant of a railway, and upon the proper equipment of the train, and the proper organization and handling of the wrecking gang, depend in great measure the promptness, efficiency and economy of the work of clearing the track and resuming traffic after a train accident, or providing temporary connections at washouts, landslides, etc. The trains should be stationed at division points, where men and locomotives are immediately available, and supplies of bridge timbers should also be kept at these points for repairs or temporary structures. The number of these trains and the length of division to which each is allotted, necessarily vary with the traffic conditions. The methods of operation will vary in each case, in accordance with the nature of the accident and the work to be done, but while in case of train wrecks it is generally of the first importance to remove the wreckage as quickly as possible from the track, so that provision can be made to carry on the traffic, this should not be done recklessly by the smashing of cars or other equipment which may with a little care and clearheadedness be moved out of the way for future attention.

One of the most important appliances for the wrecking train is a steam crane or derrick car capable of lifting cars or even engines bodily, thus avoiding the necessity of having to break up heavy wreckage in order to clear the track. The machine should be able to swing a box car clear of the track and to raise it high enough to place the body on its trucks or on a flat car. Many of these wrecking cars are heavy flat cars fitted with steam jib cranes. The Atchison, Topeka & Santa Fe Ry. has a wrecking car with a steel frame 42 ft. long, mounted on three trucks and carrying a crane of 35 tons hoisting capacity. The boom is 33 ft. long, with 1-in. steel cables; the hook will reach to the rail and has a clear lift of 18 ft., with a hoisting speed of 10 ft. per minute. For side lifting, a base 19 ft. wide can be obtained by steel jack arms pivoted to the base of the A-frame of the

crane, the jacks being supported on blocking. This machine weighs about 68 tons. A steel wrecking car on the Norfolk & Western Ry. is 22 ft. long and 10 ft. wide, weighing 55 tons. The crane has a radius of 14 to 20 ft., and is designed to hoist 25 tons at 16 ft. radius, either in front or at the side, outrigger supports being used in the latter case. The powerful 30 to 40-ton derrick or steam crane is a most economical wrecking tool, although some few roads do all the work by lines and jacks, smashing up freight cars if necessary in order to clear the track, and using small derrick cars only for picking up the wreckage and freight. This, however, is not a commendable practice. Derrick cars may be fitted with hoisting engines, as in Fig. 222, or may have the hauling rope attached to a locomotive, the former being the better plan as a rule. The Chicago, Burlington & Quincy Ry. uses a heavy 40-ft. derrick car having two masts, one operated as a derrick by hand gear, and the other having the rope led down through the floor and between the sills to the rear of the car, the end of the rope having a shackle by which it can be attached to a locomotive. Hoisting can

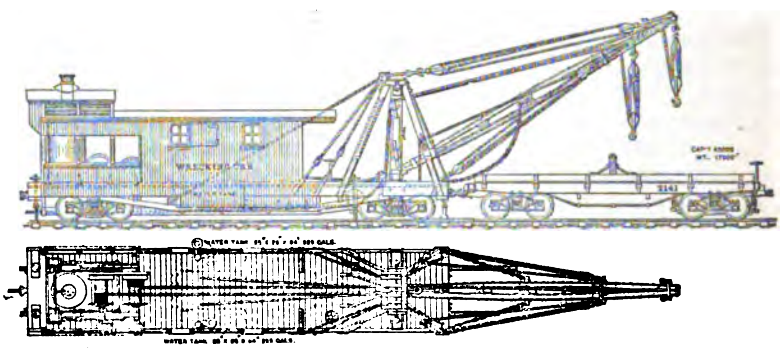


Fig. 222.—Wrecking Car.

be done much more effectively by a wrecking crane than by a rope attached to a locomotive.

All parts of the derrick and machinery should be designed with a high factor of safety, to withstand the impact due to sudden heavy shocks. The hoisting tackle should be of chain or wire rope for very heavy weights, and the best quality of pure manila rope for lighter weights. Only iron or steel tackle blocks should be used in lifting. A spring shock-arrester may be attached to the lower tackle block, consisting of a cylindrical case containing a heavy coiled spring carrying the hook bolt to which the load is attached. Steam wrecking machines should have sills of plate girders, I-beams or channels, sufficiently deep to give vertical stiffness, and well braced laterally. The frame for the machinery should be of heavy iron or of steel, with the bearings for the movable parts formed in them. The power should consist of at least one pair of reversible engines, coupled together, and the crane may be mounted on a turntable, the boiler, coal bunker and water tank forming the counterbalance to the boom. The machinery should have lifting, lowering and revolving motions, raising and lowering motions for the boom, and self-propelling gear, while provi-

sion should be made for revolving the crane in either direction without reversing the engines. Straight booms are usually of I-beams or channels, while curved booms are usually plate girders. To anchor the car while making a side lift, two or more outriggers are used, each consisting of a pair of I-beams, placed below the sills, and so fitted that they may be run out on either side, the outer ends being supported by jacks or blocking. Screw jacks to support the car frame, and rail clamps to hold the car down to the track are also provided. A steam capstan (or vertical drum) on the car would be very handy for special hauls when the derrick is under load, and would thus replace specially-rigged hand tackle. A device used for similar purposes is a portable hand hoist or crab, Fig. 223. Hydraulic jacks are the most important tools, being second only to the derrick. A set should include jacks of 10 to 30 tons capacity, and, at least, one pair should be fitted with claws. They should have thumb-screw releases. The common wrecking frog consists of a heavy bent bar, the upper end of which is pivoted to a support which straddles the rail, the feet of this support and the free end of the bar having spurs to bite into the ties or blocking and prevent slipping under a load. With these are used wedges of wood, plated

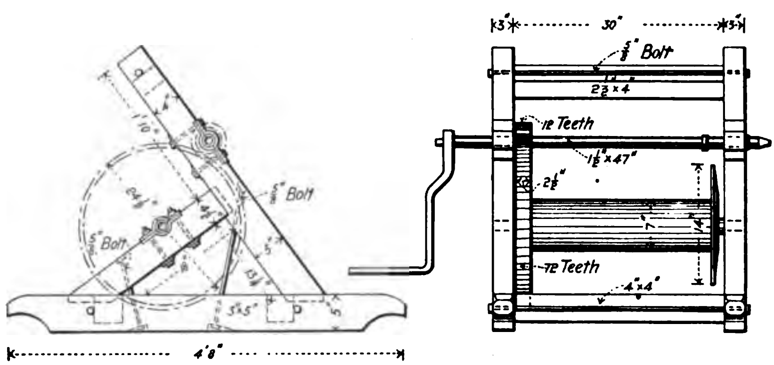
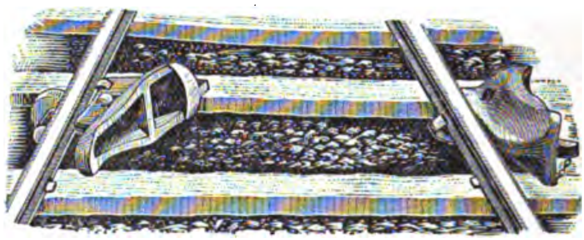


Fig. 223.—Wrecking Crab or Hoist.

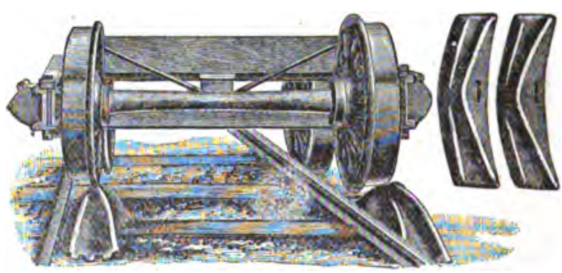
with metal, the "long wedge" being 6 ft. long, with both ends inclined, and the "short wedge" only 3 ft. long, with one end inclined. Various forms of metal wrecking frogs are used, being placed on or at the side of the rail, as shown in Fig. 224.

The organization of the wrecking force is an important consideration. It is best to have the force in charge of the motive power or operating department, and the gang should be composed of shop men, as they are familiar with car and engine work, and with the use of tackle in heavy hoisting, while the same men are available in each case and are thus experienced. The crew of a wrecking train should consist of 15 to 20 men, including a foreman. All should have had some experience in this line of work; at least six should be familiar with the use of hydraulic jacks and all kinds of rigging, and two should understand how to splice ropes, and make hitches and knots of the various kinds. At night, the wrecking foreman should carry a colored lantern to distinguish him from the rest of the gang. The foreman or one of the men should be competent to tap the wires at

the work and so open communication with headquarters. One man should be assigned to handle the engine of the wrecking car. Another should have charge of the wrecking cars, and it should be his duty to see that all rigging is in perfect order for emergencies, and in case a rope, chain, block, jack or any other tool has been broken or damaged at the last wreck, have it repaired or replaced. This man should be a good mechanic and understand how to handle and repair hydraulic jacks and keep them in perfect order. If any of the ropes have been placed in the car wet or dirty they should be washed off, thoroughly dried, neatly coiled, and placed in their proper location in the car. All wrenches should be cleaned, oiled and wiped with waste. There should be a particular location in the car for each of the tools, so that any of the wrecking crew may go to the car and pick up any tool at once. The man in charge of the car should have a complete list of all tools which belong in the cars, and should proceed immediately



Norwood.



Alexander.

Fig. 224.—Wrecking Frogs or Car Replacers.

after the wreck is cleared to check up his tools, and in case any are missing, report them to the proper superior officer to be replaced. The tools of each wrecking car should be painted or marked in a distinctive manner.

The tool and living car should have a tool room (with racks for ropes and tools and fixed clamps for jacks), kitchen, office and living room, with berths and table. Steam-heating pipes, a stove and a boiler for making coffee should be provided, in order to make the men comfortable and to furnish refreshment during their heavy work. A powerful locomotive should be assigned to the wrecking train, especially if it has to haul on the derrick lines.

Torches and other open lights are a source of danger, especially when there is oil or other highly inflammable material exposed. An electric arc

light would add greatly to the convenience and safety of wrecking operations, and it has been suggested that an electric searchlight, mounted on the derrick car, would be specially valuable, as its light could be turned to any desired part of the work. The Pennsylvania Ry. has a car for this purpose, fitted with power for 10 or 12 lamps, the lamps being mounted on tripods, 25 ft. high. The poles are carried in a rack on the roof. The car is carried on two four-wheel trucks, with track clamps at the ends of the frame, and is fitted with an engine, boiler, dynamo and large amount of supplies. On the Ohio Division of the Erie Ry., a revolving headlight is located on the roof of the derrick car. Two sizes of oil torches are used, the larger ones mounted on wooden posts placed at convenient points, and the smaller ones being carried by hand. The Wells light, which burns a large flame of oil sprayed by compressed air, is much used for wrecking purposes. Ordinary hand lanterns are used in working around inflammable wreckage. Where oil is exposed, as in the case of wrecked tank cars, it should be covered with earth or cinders before any work is done around it and before any locomotive or steam derrick is allowed to approach closely. If this cannot be done, a number of empty cars should be coupled between the locomotive and the derrick car, so as to keep the former at a safe distance. Lighting by fires of wood taken from wreckage or cars is objectionable, but such fires may be required in inclement weather.

For the care and transportation of injured persons, an ordinary car is

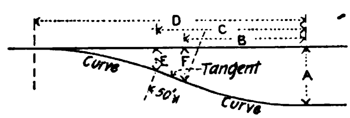


Fig. 225.—Diagram of Temporary Track for Passing Around a Wreck; So. Pac. Ry

better than a parlor or sleeping car, owing to the winding entrance of the latter. Stretchers should be about 7 ft. 3 ins. long and 21 ins. wide, and may be placed across two reversed seat backs, which gives them about the right height for convenient medical attention. In case of cattle train wrecks, the uninjured stock should be transferred promptly, and badly injured cattle must usually be killed on the spot. With refrigerator cars, special care should be taken to replace the ice and put scattered freight back in one of the least injured cars.

In case of accident, the nearest section foreman must at once proceed with his whole force to render assistance, even if it is not on his own section, and if notified of a broken rail on an adjoining section he must at once make the track safe for the passage of trains. When assisting a train delayed by accident, the foreman will act under the orders of the conductor (or such other person as the superintendent may designate) until the arrival of the roadmaster, trainmaster or the foreman of the wrecking gang. The roadmaster, supervisor or engineer should proceed at once to the wreck. The foreman must appoint watchmen to protect property at wrecks, etc., and must make a report of every accident, large or small. A natural eagerness to get the track clear must not lead to unnecessarily rough or careless handling of cars or freight, or to the destruction of the same. Note should be made of the style, initial or name, and number of all cars destroyed in

the wreck or broken up and burned as wreckage. If cars are piled up, the top ones should first be removed, and any tilted cars blocked or upset to prevent their falling over during the work. On double track, attention should first be paid to clearing one track. In some cases it may be necessary or advisable to build a temporary track around a wreck or washout, and Fig. 225 shows the standard plan of the Southern Pacific Ry. for such work, the dimensions of the lettered parts being given in Table No. 36:

TABLE NO. 36.—LAYING OUT TEMPORARY TRACKS AROUND WRECKS AND WASHOUTS; SOUTHERN PACIFIC RY.

A, ft.	B, ft.	C, ft.	D, ft.	E, ft.	F, ft.
		Ten-Degree Curves.			
10	53.6	103.3	156.9	2.5	7.5
20	84.0	133.5	217.5	6.3	13.7
30	107.3	156.5	263.8	10.3	19.7
40	127.3	176.0	303.3	14.4	25.6
50	144.8	193.1	337.9	18.7	31.3
60	160.3	208.3	368.6	23.0	37.0
70	174.5	222.1	396.6	27.4	42.6
80	187.8	235.0	422.8	31.8	48.2
90	200.2	247.0	447.2	36.2	53.8
100	211.9	258.3	470.2	40.7	59.3
		Fifteen-Degree Curves.			
10	42.2	92.0	134.2	2.3	7.7
20	66.2	115.4	181.6	5.7	14.3
30	85.0	133.7	218.7	9.5	20.5
40	100.8	149.2	250.0	13.5	26.5
50	114.7	162.6	277.3	17.5	32.5
60	127.2	174.4	301.6	21.5	38.3
70	138.7	185.6	324.3	26.0	44.0
80	149.4	195.6	345.0	30.3	49.7
90	159.2	204.8	364.0	34.6	55.4
100	168.5	213.5	382.0	39.0	61.0

The conductor's report of an accident should be full and complete. The following form is used on the Erie Ry., the conductor giving only the letter of each question:

......................Station, ...190....

To..........................Supt. Time sent........M. Time received........M.

Train No. .... Conductor......................

Engine............ Engineman......................

A. Time and place of accident. (State also if on main or side track, company or individual siding, at frog or switch, in fill, cut, or on level)......................
B. What caused it?..
C. Were any persons injured, and to what extent? Give name, age, residence and occupation and what was done with the persons..............................
D. Which track is obstructed, and which clear?...................................
E. Which track can be opened first, and how soon?................................
F. What crossing-switches or sidings, east and west of obstruction, can be used to pass trains around?..
G. How long will it take to get track clear so that trains can pass?..................
H. Will the derrick-car be required, and which way should it be headed to work to advantage?..
I. How much force is wanted to clear the obstruction?............................
J. Is the track damaged, and to what extent? Have trackmen been notified?..........
K. Is engine off track, or damaged?..
L. What position is engine in?..
M. What position are cars in?...
N. How many cars are broken and off track, loaded? (Give numbers, initials and kind)
O. How many cars are broken and off track, empty? (Give numbers, initials and kind)
P. How many cars and kinds are wanted to transfer freight in?......................
Q. What does lading of cars consist of? What amount of damage to lading?..........
R. How many cars next engine?..
S. How many behind cars wrecked?...

The quickest way of notifying the wrecking gang is by means of electric bells connecting the dispatcher's office with the shops where the men usually work, the men starting for the wrecking train as soon as they hear the bell. Whistle signals may also be given. There may be electric bells in the

houses of the wrecking foreman and of some of the men, so that they can be promptly notified at night, to these men being assigned the duty of calling others in the neighborhood. A telegraph operator should be sent with or soon after the train, unless the foreman is an operator, so that the head office may be communicated with and advised as to the progress of the work. When the force arrives at the wreck, the man in charge should organize the men for work and also arrange for the distribution of hot coffee and rations in protracted work, and for the cooking to be properly done. If he sees that it will take longer than 12 to 15 hours' work, and he has sufficient force, it should be divided into a night and day gang; the force not on duty to be kept entirely away from the work, resting and getting ready for their shift. As soon as the first gang has finished its time, the second should be ready to carry on the work. If the force is not adequate to be so divided, then there will be more accomplished if they are worked steaily through the day and then required to rest, than by trying to work the same men night and day.

As already noted, the equipment and operation vary according to the traffic over the road, and the nature of the accident, but from the following particulars of equipment of wrecking train and organization of wrecking gang on several roads, may be obtained a very good idea of the general practice:

Burlington & Missouri River Ry.—There are regular wrecking outfits at main points, and smaller outfits stationed at division points at long distances from the main points. The wrecking train consists of a derrick car, three tool cars, a riding car and a sleeping car. The riding car is used by the men in going to and from wrecks, and to dry their clothing in when wet. The sleeping car is made over from an old passenger car, and has sleeping capacity for 24 men. It has iron bunks (single on one side of car and double on the other), steel spring mattresses, wash sink, water closet, and a stove at each end. The smaller outfit consists of blocking, jacks, rope, etc., loaded in two box cars that could be got to a wreck promptly and track cleared or constructed around the wreck. Then as soon as possible a regular wrecking outfit is sent out and the wreck picked up with as little loss to property as practicable. The regular wrecking car has an oak mast and boom mounted on a strong car specially made. The mast is about 14 ins. diameter in the center and 37 feet high above the car bed, pivoted 18 ft. above the rail at the top of a strong frame, so that it can be lowered down and laid on top of the car, together with the boom, when not in use. The boom is of the same dimensions, and is trussed with 1-in. rods on the sides. It can pick up a loaded 34-ft. box car and place it on its trucks in front of the derrick.

Heavy base timbers mounted with channel irons are placed on rollers under the car bed in such a way that they can be pulled out and blocks put under the ends; this, with strong braces from the ends of these timbers to the top of the mast frame, makes a firm base. For heavy lifting, guy lines are run from the top of the mast to anchors or deadmen in the ground. The power is derived from an oscillating engine with two cylinders 10 x 12 ins., acting on friction drums and spools with slow and fast motion, as desired. The derrick is rated at 35 tons capacity, but heavier loads have often been handled, and derricks of greater capacity are now to be used on account of the increased weight of engine and cars. It enables the gang to take loaded

cars that are off the track or have trucks smashed, and set them on one side, working through a wreck and cleaning the track without breaking cars or wreckage any more than necessary. Later on, they pick up the stuff and put it back on the track, or load on cars such wreckage as cannot come out on its own wheels.

The car repairing crews at the main division points are organized as wrecking gangs. These men sleep in a car attached to the wrecking train, and are always ready for duty, by day or night. The foreman, who sleeps at home, is connected with the dispatcher's office by telephone. When the derrick is run out to a wreck, each man gets to his position immediately. The boom and mast are raised, guy lines run out, and the time taken in getting everything ready is about 20 minutes. There is 1 man at the engine, 1 in front of the drums, and 1 at back of the drums to take care of ropes, 1 on the deck in front of the derrick to receive signals from the foreman and give them to the engineman by the bell, and 2 in the rope car next to the derrick, making 7 men in all, besides the foreman. There are no special rules in regard to handling the work, except that if a wreck occurs after regular working hours (which are from 7 a. m. to 6 p. m.), the shop whistle is blown six times to call the men together in case they should be away from the sleeping car. This is repeated two or three times.

Erie Ry.—The train (consisting of a hand derrick, a 25-ton steam derrick and 3 flat-cars) is in charge of a wreck foreman, who is always in the neighborhood during the day, while another man is in charge of the tools and sees that everything is returned to place or accounted for before the car leaves the wreck. This man stays in the neighborhood of the car. The tools are marked distinctively. The wrecking organization is under the division master-mechanic, and car-shop men form the wrecking gang, being better qualified than the section men on account of their familiarity with car work and tools in their daily work. The work is in entire charge of the wreck foreman, who is held responsible for its proper conduct. Nobody is allowed to interfere with him, and he tells the dispatcher what movements he wants made. For heavy work, about 16 men are employed; 2 foremen and 14 men under them, but for ordinary wrecks of two or three cars not more than 10 or 12 men are employed. They are assisted by the section gangs are required. With very bad wrecks, the wrecking gangs from adjacent divisions are combined. Every baggage car is furnished with an ordinary frog and wedge, and with the necessary chains for doing light wrecking. Jacks, wrecking frogs and wedges are kept at all important telegraph stations and block signal towers, the section foremen being responsponsible for keeping them in proper condition. By day, a whistle signal calls the wrecking gang to the train, and by night there is a system of callers, certain men being called by a man from the station, and in their turn calling others..

Fitchburg Ry.—The wrecking train at Boston consists of one flat car and two 56-ft. box cars (which were formerly baggage cars), fitted with passenger trucks, air brakes, passenger lamps and steam heat. The flat car has the usual iron crane on its deck, besides two sets of freight car trucks, one locomotive truck, rail benders, rails of various lengths, car replacers, etc. At the side of the track where the train stands are kept two extra freight trucks, so that those used on a trip may be at once replaced on the return

of this car. The first box car contains blocking of all sizes, from blocks 12 × 12 ins. to buckets of ½-in. shims. There are also a railway tricycle, picks, axes, saws, and various tools, bushel baskets for gathering up grain, a barrel of sand for use in icy places, shovels for working earth, manure forks. ice tongs, cotton bale hooks, bolts, rail spikes, wooden levers for carrying carboys of acids which cannot be handled, and half a dozen devices called "bee hives," which are truncated pyramids of heavy plank about 4 ft. high and 2 ft. base, to rest a car body on so as to allow of removing the blocking.

The second box car is provided with lengthwise cushioned seats for the men, and contains oil-cloth covers for perishable freight in stormy weather, chains, jacks, bridge tools, oil suits for the men, hip boots, etc. The car is fitted with a water-closet, cooking stove, ice water tank and wash basin with running water and towels. The pantry contains canned baked beans, canned salmon, deviled beef, luncheon beef, coffee, tea, a barrel of hard tack, and many kinds of preserved foods. In this car are also a complete telegraph outfit, a tent and poles to protect the operator, several short ladders which can be joined together, if necessary, coils of telegraph wire and a rope, a telegraph table, and 36 umbrellas for use in transferring passengers around a wreck in a rain storm. In one corner of this car is a stateroom for the master mechanic, with a berth to let down from the wall; this has a mattress, sheets and pillows, and a rubber blanket to put over the mattress in case a bleeding person should have to be carried on it. There are closets full of old clothes, and by using a window and drop shelf in this stateroom an inside private or public telegraph office can be made.. In the rear end of this car are lanterns, tackle and falls of several sizes, torpedoes and torches, ropes, and boat hooks for getting timbers out of water. The train is equipped with the air signal, and for backing up there is a large warning gong on the rear of the last car.

There is always an engine with steam up coupled to this train, which stands just outside the roundhouse. Any available engine is used, and when thus attached, a card bearing its number is brought into the master mechanic's office and placed in a holder over the telegraph operator's desk. This enables him to get his train order without delay. The wrecking crew consists of 20 men, and they are at work in the yard, the car shop, the machine shop and the roundhouse. A push-button in the master mechanic's office connects with a compressed air whistle in the car shop, one in the machine shop and another outside. These whistles call the men to the wrecking train, and they are tested every day at 4 p. m. In addition there is a large bell in the roundhouse struck from the master mechanic's office by compressed air at the same time. The bell is used to prevent confusion with locomotive whistling. The code of signals on the bell and whistle is as follows: One stroke and blast—test; two strokes and blasts—any emergency when men are wanted; three strokes and blasts—a wreck in the limits of the Boston yards; four strokes and blasts—a wreck out on the road. When these are heard the men run to the train. It is the duty of one to get a lump of ice and put it into one of the box cars, of another to attach a hose (always ready and on a plug near by) and fill the tanks of the box car. Meantime the engineman has got his orders from the dispatcher, and as soon as the men are on board the train starts. The rails of the whole siding on which the train stands are kept sanded, so that no time may be lost from

driving wheels slipping. Late at night when all the wrecking crew are at home (except the engineman and fireman), this train has been fully manned and got under way in 22 minutes.

New York, West Shore & Buffalo Ry.—The clearing of wrecks is in charge of the roadmaster. The motive power department furnishes four men, one of whom is called the wreck master, and he has charge of the three mechanics sent with him and of the handling of the equipment of the wrecking train. If the wreck is a large one, the master mechanic is asked to send as many additional shop men as may seem necessary. After the train is at the point of action, the operations are in charge of the roadmaster, who has collected as many of his foremen and sectionmen as necessary, and either the superintendent or trainmaster is present, but only to assist, as it is believed that only one person at a time can successfully direct the work. There is always an abundance of ideas as to how the work should be done, and if a chance were given to try them all the road might remain blocked indefinitely. Every freight train is furnished with a set of wrecking frogs.

Northern Pacific Ry.—The wrecking outfit consists of a derrick car, tool car, truck car and blocking car, all equipped with air-brakes. The derrick has a lifting capacity of 20 tons. The truck car carries five freight car trucks of 40,000 lbs. capacity, one engine truck, and two pairs of 33-in. cast iron wheels with standard journals. The blocking car carries a full supply of hard and soft wood blocks, 200 oak wedges and one small portable building for an emergency telegraph office. The equipment of the other cars is given in Table No. 37. The wrecking gang is in charge of the foreman of car repairers, and consists of eight men, who have regularly assigned

TABLE NO. 37.—EQUIPMENT OF WRECKING TRAIN: NORTHERN PACIFIC RY.

Derrick Car.

1 truck line, 2½ ins. diam., 250 ft. long.
1 truck line, 2½ ins. diam., 200 ft. long,
2 second-hand steel rails,
4 iron-bound wedges,
6 switch chains,
3 truck chains,
2 wire cables, 1¼ ins. diameter.

Tool Car.

Heating stove,
Hand saws,
Axes,
Adzes,
Wheel gage,
Steel wrenches,
Soft and chipping hammers,
Track shovels,
30-in. steel bars,
12 torches,
16-ft. ladder,
Drift bolts, assorted sizes,
Coupling links and pins,
8-in. and 12-in. pony jacks,
Standard frogs,
Switch chains,
Torpedoes,
Portable stretcher,
2 gallons alcohol,
Packing hooks and spoons,
12 grain sacks, 2-bushel,
Water barrel,
Cross-cut saws,
Hand axes.
Sledge hammers,
12-in. and 15-in. monkey wrenches,
Spike mauls,
3-in. rolling line,
Picks,
1 pair of climbers,
Scoop shovels,
Pinch bars,
Cold chisels,
Clevises,
4 pairs rubber boots,
Pair patent frogs,
Iron-bound wedges,
Red flags,
Red, white and green lanterns,
Oil and waste for packing,
6 baskets (grain), 2-bushel.
6 water pails,
Standard journal brasses and wedges,
12 assorted journal brasses for foreign cars.
2 hydraulic lifting jacks, 15 and 20 tons,
2 ratchet lifting jacks and levers,
A few hundred feet of spare 1-in. to 2½-in. guy lines and snatch blocks,
A small coil of telegraph wire and a few insulators and other telegraph supplies necessary to start an emergency office.
A full set of edge-tools, the personal property of the foreman of the wrecking crew.

duties, and are thoroughly organized. When a wreck is reported, the foreman is first called; and the caller then calls one of the crew, who in turn

calls another and starts for the wrecking train. The second man calls the third and starts for the train, and so on until the crew is all on hand. By this system, in emergency, the crew has been on hand 15 minutes after the word was given. For night work there are six large torches.

Pennsylvania Ry.—Each division wrecking train is composed of tool car, derrick car, and such maintenance-of-way flat cars as may be necessary. Single derrick cars have derricks of 5 to 15 tons capacity, while double cars have two 15-ton cranes. Tne wrecking gangs are in the immediate charge of the conductor of the work train, who, as a rule, is also foreman of the wrecking gang. The supervisor or his assistant is usually in attendance at wrecks of any importance. The custom is to assign men in the gang to handle certain tools, the detail of the work being in charge of the supervisor or the foreman of the gang. The Wells light is used in night work. Table No. 38 gives a list of the equipment of the wrecking trains:

TABLE NO. 38.—EQUIPMENT OF WRECKING TRAIN; PENNSYLVANIA RY.

10 pieces of blocking	7 × 8 ins. × 5 ft. 7 ins.
8 " " "	7 × 8 " × 2 " 9 "
12 " " "	7 × 3¾ " × 1 " 10 "
20 " " "	7 × 8 " × 5 " 7 "
12 boards, hard wood	6 × 1¾ " × 1 " 6 "
12 wedges, hard wood	3½ × 4 " × 1 " 8 "
1 rope, 1¾ ins. diameter	300 ft. long, 2 and 3 sheave blocks.
1 rope, 1¾ ins. diameter	200 ft. long, 2 and 3 sheave blocks.
2 tank ropes, 2½ ins. diameter	60 ft. long.
2 " " 2½ " "	30 " "
2 " " 2 " "	30 " "

4 patent chains,
1 truck chain,
6 dog chains,
3 truck connections,
2 pulling bars,
4 fire buckets,
2 ropes, ¾-in., for fire hooks,
1 snatch block,
2 grappling irons,
2 fulcrums,
1 track gage,
½ coil telegraph wire,
2 large levers,
2 small levers,
3 fire hooks,
1 wooden mallet,
1 ratchet,
2 drills, 1-in.,
2 small vices for splicing wires,
1 pair telegraph climbers,
6 coupling pins,
6 coupling links,
4 coupling links (crooked),
4 body pins, 1¾ ins.,
2 draft pins,
2 short 15-ton jacks,
2 long 15-ton jacks,
2 long 10-ton jacks,
1 broom,
1 dusting brush,
6 oil cans,
6 boxes of matches,
25 signal caps,
150 spikes,
1 fire shovel,
25 three-bushel bags,
10 lbs. waste,

2 patent frogs,
4 pinch bars,
2 claw bars,
1 spike hammer,
2 sledges,
4 jack braces,
4 jack hooks,
1 auger, 2½-in.,
1 " 2-in.,
1 " 1½-in.,
1 " 1¼-in.,
1 " 1-in.,
2 hand saws,
1 axe (hand),
1 soft hammer,
2 iron hammers,
2 monkey wrenches, 14-in.,
2 monkey wrenches, 20-in.,
1 carpenter's chisel, 1-in.,
1 carpenter's chisel, 2-in.,
6 chipping chisels,
2 files, 14-in.,
1 wheel gage,
2 wash basins,
2 pole axes,
6 torches,
8 white globe lamps,
2 red globe lamps,
4 side lamps,
1 sponge hook,
16 clay shovels,
14 coal shovels,
4 spades,
16 picks,
4 cold cutters,
1 soap box,
1 match box.

Washouts and Burnouts.

In times of continuous heavy rain, floods and freshets, or in protracted droughts, when there is danger from fire, precautionary measures should be taken by keeping fire tubs and buckets full, clearing snow and drift

from all waterways, and by putting on extra watchmen and trackwalkers to look after the safety of structures and watch for indications of undermining of foundations, slips in cuts and washouts in banks. During such times the section foremen and roadmasters should keep the superintendent constantly informed as to the condition of the road, so as to facilitate traffic by preventing delay in running trains cautiously where the road is perfectly safe and by getting prompt attention to any point of danger. After a flood has subsided, a special examination should be made of the condition of foundations of abutments, piers, trestle bents, etc., as many accidents occur from the collapse of structures which have been undermined.

Damage to falseworks, timber abutments, temporary trestles, etc., by logs, etc., carried down by the current, may be prevented by a boom of logs on each side of the stream, with the upper end of each boom attached to the shore. These will guide the floating objects safely through the waterway. At trestles, bridges, etc., which are threatened by logs, drift, ice, etc., men should be stationed to guide floating objects through by means of poles, so as to prevent any obstruction. Ice jams or gorges may be shattered and broken up by explosives. A good method is to put about 100 lbs. of blasting powder in a 4-gallon can and sink it through a hole into the water, allowing it to drift some distance under the ice, holding it in position by a rope tied to a stake at the hole. The charge should be exploded by an electric blasting battery, and not by a time fuse. Washouts can sometimes be prevented by watching, as above advised, but as a rule they occur suddenly and under such conditions as to floods, etc., that the only thing to be done is to prepare for repairs at the earliest possible time.

In case of a washout, burnout, wrecked structure, caved-in tunnel, etc., the foreman should first take steps to send out flagmen to stop trains, and then report at once to the proper track official and superintendent, stating in full the exact location of the accident, the number or name of structure, character and extent of damage, etc., and particulars of train wreck (if any). He should then do what he can with the means at his disposal to prevent further damage, and prepare for the repair work. The wrecking train and gang will then be sent out promptly, equipped with the necessary plant and tools. Further cutting away of the banks of a washout may be checked by covering them with stone, logs, or brush and trees interlaced to form a mattress, or even by rough cribbing to cut off destructive currents or eddies. It is generally useless to try and fill a gap with anything but stone if a current is flowing through it. If the water is too high or turbulent to allow of commencing the repair work at once, the time may be profitably spent in building trestle bents, cribs, etc., and filling sacks with earth, ready to be put in as soon as possible, as it is of the greatest importance to get the road opened for traffic.

Cribs may be built of old bridge timbers, logs or ties. The latter will be about 8 × 8 ft. in plan, with from two to four ties in each course, and a single crib of this kind will suffice for a height of 6 to 8 ft. For a greater height, there should be two cribs side by side, or a wider crib with the two rows of ties transverse to the track, these ties overlapping side by side. The cribs should be brought to a level surface, and topped by regular trestle caps 10 to 16 ft. long, to support the stringers. For wide openings, cribs

(with one end pointed to facilitate handling in the current) may be towed or floated out to form foundations for crib or frame piers, being sunk by stones onto the natural bottom or onto a pile of stone first dumped. An opening of 15 to 25 ft., with firm sides, such as a washed out culvert, may be spanned by two 12 x 12-in. timbers under each rail (6 ins. apart), resting on a sill at each end. These are crossed by about four smaller timbers carrying two 12 x 12-in. stringers for the rails or ties.

A pile driver is a very important implement where large washouts of banks, trestles or bridges have to be dealt with, while steam shovels can be used to advantage at landslides. Track pile drivers are heavily built flat cars, with leaders carried by a frame on a revolving bed supported by a turntable on the deck of the car. Usually, the engine and boiler are at the rear end of the bed and counterbalance the leaders, but in some cases the former are stationary at the rear end of the car. The bed has a lateral travel of 16 to 20 ft. over the turntable to allow of setting piles a panel length ahead of the car, and 16 to 22 ft. on either side of the center of the track. The leaders are usually pivoted about 12 ft. above the rail, so that when lowered for transportation the upper end rests on the engine house roof, while the lower ends project in front of the car. This makes it necessary to put a flat car ahead to enable the pile driver to be coupled into a train. A pile driver on the Chicago, Milwaukee & St. Paul Ry., however, has a curved heel on which the leaders roll backwards and downwards, so that when lowered they do not project beyond the car. The 40-ft. leaders are pivoted about 26 ft. above the rail to swing laterally, for driving brace piles, etc. A pipe and hose for water jet may be added to the equipment, and some pile drivers carry a steam pile hammer as well as the usual 3,000-lb. ram.

The pile driver car of the Missouri Pacific Ry. is 55 ft. long, and the leaders are carried 16 ft. ahead of the car body, so that 10 ft. panels can be built. It has a reach also of 14 ft. on either side of the track. The leaders are 40 ft. long, 20¾ ins. apart in the clear, faced with 8-in. steel channels, and are hung on hinges. A 3,000-lb. hammer is used. The pile handling and hammer lines are led over different sheaves on the leaders and over guide pulleys back to separate drums on the engine, which has two cylinders 7½ x 10 ins., and two 12-in. drums. Steam is supplied by a vertical boiler 45 ins. diameter and 6 ft. high. The car is fitted with two 1½-in. manila hammer lines, and two 1¼-in. pile lines with one end spliced to the ring of a ½-in. crane chain 7 ft. long, the free end of the chain having a hook. Next to the pile car is a flat car equipped with a 20-ton hydraulic jack, 6 screw jacks, 2 snatch blocks for 2-in. line and 2 for 1½-in. line, 3 sets of blocks and falls for 1-in., 1½-in. and 1¼-in. line, 600 ft. of 1¾-in. rope, hand hoist (Fig. 223), 6 sets of carpenter's tools, and a supply of bars, wrenches, chains, hauling lines, axes, spikes, nails, etc., a supply of coal and a 2,000-gallon water tank. The crew for this car consists of an engineman, fireman and 7 men, or 24 men for emergencies, of whom 8 are laborers and the others bridge men. This crew will drive 5 bents of 4 piles each, cut them off, and fit caps, stringers, ties and track in 10 hours.

If a temporary trestle is required, piles may be driven, cut off to height and connected by caps drift-bolted in the usual way. If a pile driver is not available, piles or timbers may be put in place singly by a hand derrick,

"jumped" and churned by means of ropes to sink them into the bed, and secured to each other by plank braces as soon as they are secure, using the planks to guide the additional piles. In this latter method the man in charge will not care about getting his piles evenly spaced, but will try to locate them in holes and soft places. Another method, which may be used where there is hard bottom, is to make soundings for each leg of the bent, cut the posts to length, connect them by a drift-bolted cap, and a 4 x 10-in. diagonal brace and 4 x 10-in. horizontal plank at what will be the water line. The bents are then placed in position and connected by longitudinal bracing. If framed bents are used, they are usually of 12 x 10-in. timbers, with four posts secured to a cap and sill by dog irons or plank splices spiked across the joints, and stiffened by two diagonal plank sway braces. The middle posts should be 5 ft. apart, c. to c., and the caps 10 ft. long if outer batter posts are used, or 14 to 16 ft. if all the posts are vertical. The bents should be 12 or 14 ft. c. to c. These bents may be floated out to place and swung into place by a derrick, resting upon the bottom or upon a pile of broken stone dumped in place and leveled off. If above the water line or on dry ground, the sills may rest upon a mudsill or a row of short cross timbers. Upon these bents may be placed two or three stringers under each rail (two 8 x 16 ins. x 24 ft., or three 7 x 15 ins. x 28 ft.), and track ties laid upon these. The stringers break joints and may be secured by 6 x 6 in. triangular braces or blocks, spiked to the caps and stringers.

If the waterway is very wide, rough boats or pontoons may be built for the men in handling piles and bents and putting on the sway bracing. Great care should be taken to insure strong and substantial construction, and ample longitudinal bracing should be provided so as to distribute the pressure and prevent the collapse of the structure by undue pressure upon an unevenly supported bent. In all such work the liability of a second flood or of heavy floating pieces being carried down by the stream must be borne in mind. Mortise and tenon work should not be employed, as it is expensive, takes time, and prevents the subsequent use of the timber in other work. The timbers should be butted together, bored, fished and bolted. A handy method of fastening timbers together is to use dog irons, 12 ins. long, with the ends bent for 4 ins. to drive into the two pieces, the ends being chisel pointed, one vertically and the other horizontally. One leg is at right angles to the straight front, the other at a little more than a right angle, so as to pull the timbers together. Two dog irons should be driven simultaneously on opposite sides of the joint, so as not to displace the timbers in driving. Where spikes are used they should be ½-in. boat spikes, 8 ins. long.

Roadmasters and bridge foremen should be furnished with a complete list of plans of pile and trestle bridges, and should have blue prints showing the bill of material for from one to 30 panels of bridge deck complete. They should also have a bill of material for frame bents from 8 ft. to 50 ft. in height, showing sway braces and longitudinal and sash girts, and they should have the same for pile bents. They should have a blue print for framing bents, showing length of sills and distance between mortises and length of plumb and batter posts, so that it will not be necessary for them to do any figuring in case of a rush. The foremen in charge of emergency repairs to bridges, etc., should be selected for their judg-

ment and self-reliance as well as skill, since they may often be thrown upon their own resources, owing to the telegraph wires being down.

The following table was prepared by Mr. R. D. McCreary, Assistant Engineer, Pennsylvania Ry., to show bridge men, carpenters, etc., the necessary size of stringers for various spans, c. to c. of caps or wall plates. The table gives the width in inches of each stringer for fiber strains of 750 and 1,000 lbs. per sq. in. The former is for hemlock or pine structures of one or two spans and where the stringers extend only from cap to cap. The latter is for white oak stringers on single spans and pine or hemlock stringers extending over two spans and breaking joints. The end spans of trestles over two spans in length should be only three-fourths the length of intermediate spans, so as to equalize the stress. The stringers may be of one thickness or divided into two or more members, packed together. The table is calculated for engines having a weight of 113,800 lbs. on the driving wheels:

TABLE No. 37.—SAFE WIDTHS OF STRINGERS FOR TEMPORARY RAILWAY TRESTLES.

Span, c. to c. of caps, ft.	Load, bending moment, ft.-lbs.	Width, For 12 ins. deep. 750 lbs., ins.	1,000 lbs., ins.	For 14 ins. deep. 750 lbs., ins.	1,000 lbs., ins.	For 15 ins. deep. 750 lbs., ins.	1,000 lbs., ins.	For 16 ins. deep. 750 lbs., ins.	1,000 lbs., ins.	For 18 ins. deep. 750 lbs., ins.	1,000 lbs., ins.	For 20 ins. deep. 750 lbs., ins.	1,000 lbs., ins.
4	18,730	12.5	9.4	9.2	6.9	7.9	6.0	7.0	5.3	5.6	...	...	...
5	22,910	15.3	11.5	11.2	8.4	9.8	7.3	8.6	6.4	6.8	5.1	5.5	...
6	27,090	18.1	13.5	13.3	9.0	11.6	8.7	10.2	7.6	8.1	6.0	6.5	...
7	31,270	20.8	15.6	15.3	11.5	13.3	10.0	11.7	8.8	9.3	6.9	7.5	5.6
8	35,450	23.6	17.7	17.4	13.0	15.1	11.3	13.3	9.9	10.5	7.9	8.5	6.4
9	42,460	28.3	21.2	20.8	15.7	18.1	13.6	15.9	11.9	12.6	9.4	10.2	7.6
10	50,920	33.9	25.5	24.9	18.7	21.7	16.3	19.1	14.3	15.1	11.3	12.2	9.2
11	59,470	39.6	29.7	29.1	21.8	25.4	19.0	22.3	16.7	17.6	13.2	14.3	10.7
12	70,660	47.1	35.3	34.6	26.0	30.1	22.6	26.5	19.9	20.9	15.7	17.0	12.7
13	82,590	55.1	41.3	40.4	30.3	35.2	26.4	31.0	23.2	24.5	18.4	19.8	14.9
14	94,640	63.1	47.3	46.3	34.8	40.4	30.3	35.7	26.6	28.0	21.0	22.7	17.0
15	106,850	....	....	52.3	39.3	45.6	34.2	40.1	30.1	31.7	23.7	25.6	19.2
16	119,210	....	....	58.4	43.8	50.9	38.1	44.7	33.5	35.6	26.5	28.6	21.5
17	131,730	....	....	....	....	....	....	49.4	37.0	39.0	29.3	31.6	23.7
18	146,050	....	....	....	....	....	....	54.8	41.1	43.3	32.5	35.0	26.3
19	162,050	....	....	....	....	....	....	....	....	....	....	38.9	29.2
20	178,250	....	....	....	....	....	....	....	....	....	....	42.8	32.1

In rebuilding the Pennsylvania Ry., after the severe damage to its line by the flood of May, 1889, the following complete outfit was prepared for feeding and housing the carpenters, telegraph linemen, laborers, etc. Two baggage cars were turned into kitchen and provision cars, and fitted with a cooking stove, tables, benches, etc., and supplied with cooking and table equipment for a strong commissary department. Two passenger cars were turned into dining cars by taking out the seats and building a plank table down the middle for the full length. Day cars were used for temporary sleeping accommodation, each man being provided with two blankets. A car was loaded with tools and materials for carpenters and trackmen, including two or three 1,000-ft. coils of 1-in. and 1½-in. rope, about 50 kegs of 6-in. and 8-in. cut and boat spikes for bracing and scaffolding use, and all the carpenters' tools that could be collected. In addition there were several carloads of 3-in. plank, 12 × 12 or 10 × 10 in. lumber for trestling, standard stringers, etc. While the river was too high and too swift for putting in the trestling, the carpenters were employed in framing caps and top ends of logs. Soundings were taken for the leg of each trestle bent, and about 2½ tons of rails were spiked to the first bent

got in position to sink it to the bottom through the current. The bents were 15 ft. centers. The electric lighting car of the Cumberland Valley Ry. (already mentioned) was used.

The course of operations to be pursued under certain conditions has been outlined by Mr. George J. Bishop, of the Chicago, Rock Island & Pacific Ry., in a paper read before the American Association of Superintendents of Bridges and Buildings, 1895, and from this paper the following notes are abstracted:

In making repairs across streams 10 to 30 ft. deep, with a steam pile driver car, the following organization is recommended: (1) Unload enough material to start work; (2) start a gang of men framing ties and one end of stringers and sizing both ends, sizing the end not framed back 30 ins.; (3) start pile driving; (4) have foreman and 10 men in front. By the time the pile driver has a bent of piles driven, the foreman has his staging up and height marked on the piles, and at the last blow of the pile-driver hammer the straight edge is put on and two men to each pile start sawing them off, while the driver runs back for a cap. When the piles are sawed off, the pile driver lowers the cap to position and starts for stringers for one side. The stringers are lowered to position and the driver goes back for the other side, during which time the men place stringers and finish drift-bolting the cap. The other stringers are then lowered to position and the pile driver starts for a panel of bridge ties. As soon as these are lowered the driver goes back for two 30-ft. rails. These are placed on the ties and the driver goes for a pile. It is necessary to use two rails 20 ft. long and two of 10 ft. for temporary work. Rails 30 ft. long do not always work to good advantage on 14 and 16-ft. spans; they are either too short or too long, as the rails should project over the bridge. While the pile driver is gone the track is spiked, bolted, gaged, and lined. There is then, generally, a few minutes' delay of the pile driver waiting for the men to finish. Then it starts driving the next bent. While driving this, two of the men in front are sawing off the ends of the stringers, getting ready for the next panel, and two of the men are detailed to bore and bolt up the stringers, so as to keep everything safe. These operations are continued until the gap is crossed. Of the 10 men in front of the pile driver, each has his part to look after. While the pile driver is driving the next bent, 1 man sees that angle bars, track bolts, drift bolts, and tools are ready for the next bent; 2 men are sawing off stringers; 5 are putting up ledger boards and staging, putting on sway braces and bolting up same; the other 2 men are back boring and bolting up the chord. They should have turnbuckles to pull bents square with the track and to pull the piles into place. All caps are bored out on the dump for sway brace bolts, and the gang there should do all the unloading, framing of material and piling same after framed for the pile driver to pick up. A foreman and 9 men can do this and keep material prepared for a day and a night gang. One man should be detailed from this gang to file cross-cut saws for the pile driver and the two bridge gangs. With proper management, such a gang can drive and complete six to ten panels of bridge work every ten hours, and at night three to five panels of permanent work. As the night gang has to do all the changing and coaling-up on their own time, there will necessarily be considerable loss of time to them and slower work on account of the darkness. If night work is done it will be necessary to have an extra engine tank for water for pile-driver and locomotive. The locomotive should be arranged to take water from the pile-driver tank to avoid running for water from 6 a. m. to 7 p. m., or from 7 p. m. to 7 a. m. In temporary work, where only three piles are driven to the bent, better results can be secured and fewer men are required.

If the pile driver has a reach of 16 to 18 ft., it is well to have two or three pieces of Oregon fir timber 24 x 24 ins., 50 ft. long, and use them as stringers, projecting them over the cap 10 ft. or more and laying bridge ties

and track thereon. The driver can be run out on them for driving a bent of piles, and every time one has been driven and capped the stringers can be readily moved forward to drive the next.

There are several different ways of making repairs to banks that have been badly washed at the side. One is to dig down the remaining embankment and bring up the part washed to a level. It is necessary sometimes to make a long run-off, so that grade will not be too steep, as the fill cut down is often 6 or 8 ft. below grade. Another way is to build around the break what is called a "shoofly" (Fig. 225). This is very often done, but it is not advisable except in extreme cases, as the cars are likely to run off the track, or the train to break in two parts on account of sharp curves and steep grades.

The following is recommended as the best way to make these repairs: Where embankments are half washed out and only 10 ft. deep, lay one sill 12 x 16 ins., by 10 ft., longitudinal with track, set plumb posts on that, put caps on the plumb posts, dig out the bank, project the caps through and place stringers under outside rail, resting on caps. The stringers carry the track on one side and the embankment on the other. Where the washout is 18 ft. deep, set up a plumb and a batter post on sills and sway brace the plumb and batter posts to the cap. By putting in this temporary trestle work the track is up to grade, regular trains can be pulled, which cannot be done where the embankment is cut down or a "shoofly" is put in, and it can be filled by work train or steam shovel. If by steam shovel and side plow only a few section men will be required to handle the dirt; on the other hand, if a "shoofly" is put in and filling is done with the steam shovel, it is necessary to scrape dirt off on one side and keep raising track up and throwing in line to get it back on its old centers and grade. This will require a large force of men and will cause a waste of material and delay of shovel unless they have other work in the vicinity. It is the same with embankment cut down, as a large number of men are required.

There should be boarding trains at all large washouts, or other arrangements made for the men to get their meals regularly. This should be looked after by the head of the bridge and building or roadway department, or by some one detailed by him. All bridge gangs should have outfit cars, one bunk, one tool, and one material car, so as to be ready to move upon short notice.

CHAPTER 27.—RECORDS, REPORTS AND ACCOUNTS.

Charts and Records.—Most railways keep some form of map or chart record, which shows at a glance the alinement, profile, sidings, stations, and important features of the roadway equipment. In Fig. 226 is shown a reduced specimen of a graphical chart of the Peninsula Division of the Chicago & Northwestern Ry., the original scales being 1 mile to the inch horizontally, and 100 ft. to the inch vertically. Besides giving a graphical representation and profile of the line, it locates and briefly describes all the truss bridges, roundhouses, turntables, coaling and water stations, and a record of the rails, being intended to include such physical features as pertain especially to the track and operating departments. There is also given in one corner of the sheet a geographical map of the division on a small scale. The charts are corrected once a year and new sets of blue prints are made, which are framed under glass and hung in the office, or cut into strips and

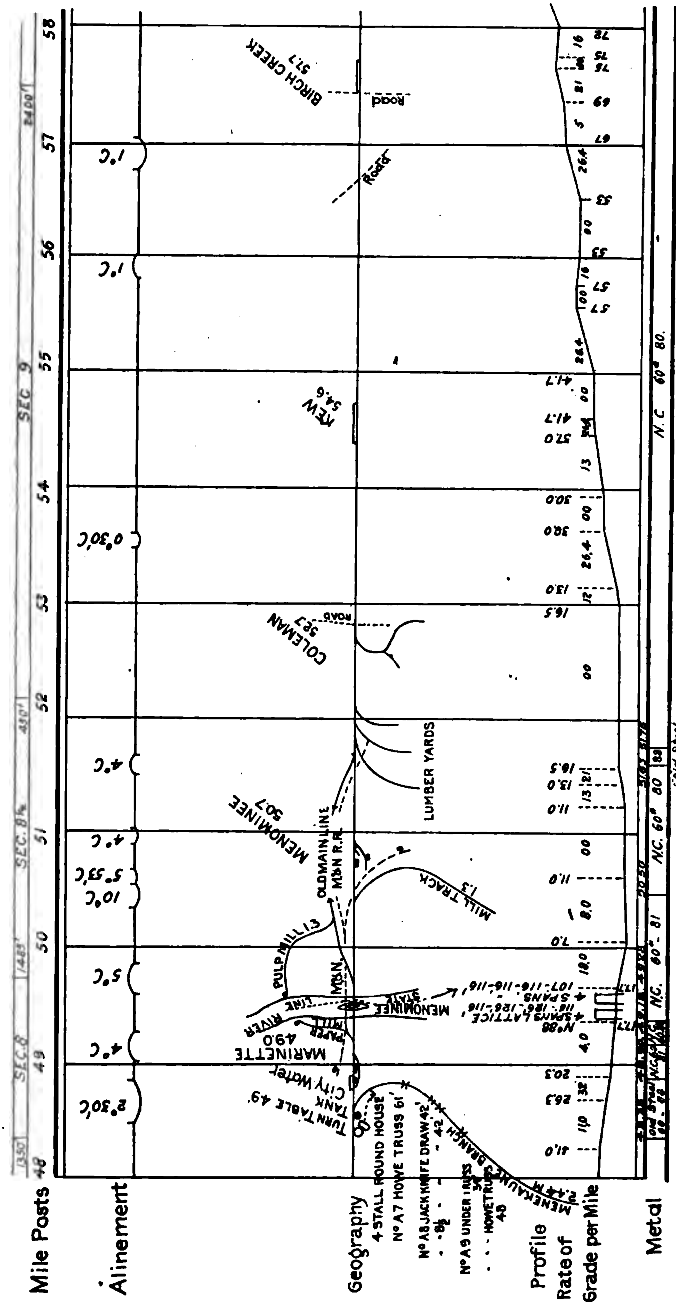


Fig. 228.—Graphical Chart; Chicago & Northwestern Ry.

folded for the pocket. The sheets are about 34 x 52 ins. inside the border lines.

The top line gives the limits of the track sections, with the number and length of same. The next line gives the miles, a vertical line being ruled across the chart at each mile. Then comes the alinement, showing the degree of each curve. Below this is shown the geography, the railway being indicated by a straight line, all bridges, road crossings, sidings and spur tracks, buildings, etc., plotted on, and particulars of spans, grades of spurs, capacity of roundhouses, etc., noted. The township and other boundaries are also marked. Under this is a profile, with bridges marked and described, and elevations and rate of grade in feet per mile also noted. The profile is broken, as required, to keep it below the plan. At the bottom of the chart are shown the make, weight and date of rails, and the length laid with each make. Station and yard tracks are only indicated, reference being made to yard plans, but exterior sidings and spurs are as shown, except that spurs to mines, etc., are not plotted to scale. With each sheet is a table showing the dates of construction from point to point, by years, and another table giving the location of each bridge, its record number, and its clearance in width and height.

A chart used on the Pennsylvania Ry. is 6 ins. nigh, folding up to a size of 4 x 6 ins., and is divided vertically by sections instead of miles, with the names and addresses of the supervisors and foremen along the top of the chart. Then comes a broad space for the plan, which shows the state and county lines, mile posts, number of tracks (and, by symbols, the weight of rail), sidings, road crossings, bridges (with their numbers), stations, signal towers (with their telegraph calls and the number of the block), etc., with notes as to special rail joints, etc. Below this is the alinement plan, showing the direction and degrees of curves, and symbols on this line indicate the character of the ballast. Below this again is the profile, with rate of grade marked in feet per mile. A more pretentious chart, intended rather for office record or file, used on the New York, New Haven & Hartford Ry., is to the scale of 300 ft. to the inch, with pages 22 x 10 ins., each showing 5,000 ft. It is divided by vertical lines making spaces representing 100 ft., and by numerous horizontal lines. It gives in separate lines the names of station agents, trainmen, roadmasters, foremen, etc., landowners, land tax, express and carriage companies at stations, etc. It gives also a track plan, and a profile indicating switchstands, bridges, signal towers, signals (with number of blades) and other equipment. The Atchison, Topeka & Santa Fe Ry. has a rail, ballast and fence record consisting of process sheets (blue lines on white ground) 13 x 8 ins., divided vertically by lines forming a scale of 1 in. to the mile, with five strips of track on each page. Each strip of track has three lines, the center line indicating the rail and ballast, and the two side lines the fences, while numbers and symbols indicate the kind of ballast, weight of rail, kind of fence, etc. The location of water and coaling stations, Y's and turntables, and the capacity of sidings, are shown on the time cards. The bridge record is a blue print list for each division, corrected from time to time. This shows the bridge number, the position as fixed by mile post and feet additional, the center height, number and length of spans, total length, description, and year of

construction. Other bridge records and charts have been referred to in Chapter 23.

In a paper on "Railway Map and Profile Records," presented to the Illinois Society of Engineers in 1899 ("Engineering News," Feb. 16, 1899), Mr. V. K. Hendricks, Engineer of Maintenance of Way of the Terre Haute & Logansport Ry., described a system based on the practice of that road. First of all, there are continuous maps of the entire road, showing right of way and property lines, section lines, railway and highway crossings, mile posts, etc., and the alinement. The scale is 400 ft. to 1 in., 100 ft. to 1 in. in towns and cities, and the sheets are 18 x 26 ins., each containing only one land section instead of a certain length of track. Then there is a set of station plans, scale 100 ft. to 1 in., showing the tracks, sidetracks, buildings and platforms, water tanks, stock pens, coal docks, etc., with the subdivision of adjacent property and all important buildings and industries within the limits of the plan, whether on railway or private property. Besides these there are miscellaneous plans, which should conform as far as possible to the standard sizes. Bridge records and fence record plans should also be kept. The working profile is usually on a scale of 400 ft. to 1 in. horizontally and 20 ft. to 1 in. vertically. A line (with a yellow mark below it) should represent the top of rail, and another line (with a brown wash below) should show the original surface of the ground at the center or the surface on one side. High and low water mark of water-courses should be marked in blue, and all elevations should be based on sea level datum. Below the profile should be a plan, the curves being represented by lines of a different color from the tangent (instead of by curves or offsets) so that the right of way lines can be clearly shown. This plan should show all the stations, sidetracks, water and coaling stations, crossings, important buildings, etc. For the use of train dispatchers and other officers there may be a condensed profile and datum map. The profile will show the location of water and coaling stations, passing tracks, car capacity of station tracks, the rating of engines over the various grades, and also the alinement, and the location, size and style of bridges. The map would show the arrangement of tracks at each station, all connecting Y tracks, distances between all connecting lines, location of water tanks, location and length of sidings, the ruling guides between all connections and the weight of engines safe to run over each stretch of track.

Reports.—The proper carrying on of the work of the roadway department and the necessity of determining the cost of the work, involves the use of various reports, note books, blanks, etc., and these should be in as few different sizes and styles as possible, so as to ensure uniformity and to facilitate filing as records or for reference. Nearly every road has its own series of blanks, and for different purposes, but a list of the principal blanks issued for reports by the engineer's department of the Lake Shore & Michigan Southern Ry. is given in Table No. 40. The table also shows the sizes of the reports (the width being given first), when and by whom made, and to whom sent. The styles of those marked (*) are illustrated herewith, and the following are some general explanatory notes:

Nos. 2 and 3 are alike except that the latter is larger, as the roadmaster will have to include the reports of all his section foremen. No. 6 has a left

hand column of items and other columns for amount and value of material received, shipped, used, and on hand. No. 8 is now sent to the principal assistant engineer, instead of to the division engineer. No. 12 has vertical columns for division or branch, between what station stakes, feet of track, which track, kind of ballast, cubic yards, and remarks. No. 17 has debit and credit columns for cords of wood and value. No. 24 is identical with No. 23, except that the leading "number of rails" is replaced by "weight per yard." No. 26 has vertical columns indicating the location and describing the style and make of frog and switch, with the date of laying and removing, and cause of removal. No. 29 is a cloth bound book, with the left-hand page for material used and shipped, and the right-hand for material received; each page is ruled for date, amount and description, and the left has a column headed "On what work used or to whom supplied," while the right has one headed "From what piece of work or from roadmaster." Tools are not to be entered, but new and old materials must be distinguished. The entries are to be made only on the left-hand page, and a list is given of the classes of work for which the material must be given separately; these include (1) main track, (2) sidetracks, (3) road crossings, (4) outside track on structures for which the railway is paid, (5) railway crossing, (6) bridge, (7) new fence, (8) old fence, (9) repairing tracks damaged by derailment, (10) constructing or extending sidetracks.

No. 30 is the roadmaster's alphabetical record of material and tools, with one column for "items" and numerous columns for amount and value of material on hand, received and shipped. No. 31 is used for the monthly pay rolls, and has 58 lines; there is one column for "items," followed by about 26 columns for amounts. No. 32 is a monthly letter report, showing the length of splice bar, bolt spacing, and year of laying. No. 33 is a home-ruled report of hard and soft wood ties, used (on main and side tracks separately), shipped, received, and on hand. No. 34 is a letter report, giving causes of the failure. No. 35 shows the number of men employed, length and kind of fence built and repaired, cattleguards built and repaired, number of post holes dug and posts cut, kind of soil, etc. No. 37 shows the hours pumped, the revolutions per minute, and the supplies received for each day, with the size of pump and number of boiler. No. 38 has two pages, with the various parts printed in a column at the left, followed by a column for "condition when inspected," leaving over half the page for remarks. Between the horizontal lines are the names of the structures as follow, having about four lines between them for the various parts: (1) Water tank, (2) coal derrick, (3) stone derrick, (4) stock chute, (5) mail crane, (6) standpipe, (7) hog drencher, (8) target, (9) windmill, (10) pumping engine, (11) coal chute, (12) coal dock, (13) elevator, (14) passenger and freight house, (15) semaphore. A separate report is used for each station and is mailed daily, with a letter if any detailed report is required.

No. 40 is similar in style to No. 4. No. 41 states the cause of delay reported by a train at a block signal. No. 42 denotes the signal, train, date, and cause of delay, whether legitimate stop, defective maintenance, defective system, fault of trainmen, or workmen. No. 44 gives the initial and number of car and the number of first-class ties and culls. No. 45 is to notify the roadmaster that ties have been shipped and are to be counted.

No. 48 describes the location, kind, capacity and condition of scales. No. 49 has vertical columns for names of men, time each day, total time, rate and amount. No. 50 is in two sizes: one with two columns for "items" and "articles and description," while the other has an additional column for remarks. Besides these there are blanks for shipments of supplies, and requisition blanks for heads of departments ordering from other departments articles and repairs too small to require a requisition on the engineer, but copies of these are sent to him as a check against misuse.

TABLE NO. 40.—REPORT BLANKS OF THE ENGINEERING DEPARTMENT; L. S. & M. S. RY.

		Size, ins.	When made.	Prepared by	Sent to
1.*	Work done and changes made	8 × 13½	M.	Sect'n foremn.	Roadmaster.
2.*	Defective steel rails removed from main track	8½ × 7	M.	Sect'n foremn.	Roadmaster.
3.	Defective steel rails removed from main track	8½ × 14	M.	Roadmaster, P. Asst. Engr.	P. A. Engr. Chief Engr.
4.*	Tools and equipment on section (2 pp.)	8½ × 14	M.	Sect'n foremn.	Roadmaster.
5.*	New and second-hand material on section (3 pp.)	9½ × 15	M.	Sect'n foremn.	Roadmaster.
6.	New and second-hand material, and new tools on division	14 × 8½	M.	Roadmaster.	G. Off. Act't.
7.*	Section and fence gang report	5¾ × 9¼	W.	Foreman.	Roadmaster.
8.*	Section and fence gang report	6 × 9¼	W.	Roadmaster.	P. A. Engr.
9.*	Extra gang	6 × 9¼	D.	Foreman.	Roadmaster.
10.*	Excavator or steam shovel	6 × 9¼	D.	Engineman.	"
11.*	Work train	5¾ × 9¼	D.	Conductor.	"
12.	Main track ballasted	9½ × 8	M.	Roadmaster.	P. A. Engr.
13.*	Extra force	14 × 8½	D.	Roadmaster.	P. A. Engr.
14.	Extra force	14½ × 9	D.	P. Asst. Engr.	Chief Engr.
15.*	Gravel and earth handled	14 × 8½	D.	Roadmaster.	P. A. Engr.
16.	Gravel and earth handled	14½ × 9	D.	P. Asst. Engr.	Chief Engr.
17.	Wood	8½ × 7	M.	Roadmaster.	P. A. Engr.
18.	Ballast	9 × 4	M.	"	"
19.*	Scrap on hand	8½ × 7	M.	"	"
20.	Rails used	9 × 4	M.	"	"
21.*	New side tracks constructed	9½ × 8	M.	"	"
22.*	Side tracks taken up	10½ × 7¾	M.	"	"
23.*	New steel rails laid in main track for renewals	9½ × 8	M.	"	"
24.	Second-hand steel rails laid in main track for renewals	9½ × 8	M.	"	"
25.	Steel rail frogs and switches removed from main track	11½ × 9	M.	"	"
26.*	Bridge and culvert inspection	8½ × 14	M.	"	"
27.*	Broken rails found in main track	8½ × 11	...	"	"
28.	Distribution of labor on section	11½ × 8	M.	Sect'n foremn.	Roadmaster.
29.	Material received, used, shipped (Book)	7½ × 10½	...	Sect'n foremn.	Roadmaster.
30.	Material and tools received, used, shipped and on hand	22 × 16	M.	Roadmaster.	P. A. Engr.
31.	Distribution of pay rolls	21 × 16	M.	"	G. Off. Act't.
32.	Broken splices found in main track	Letter.	M.	"	P. A. Engr.
33.	Ties received, used, shipped and on hand	Home ruled	M.	"	"
34.	Failures of electric alarms at crossings	Letter.	M.	"	"
35.	Fence gang work	8½ × 10¾	D.	"	"
36.*	Fencing	8¼ × 14	M.	"	"
37.	Water station	8¼ × 6¾	W.	Pump. Engr.	Mast'r Carp.
38.	Structures and appliances at stations (2 pp.)	8¼ × 14	D.	Carp. Dep. Insp.	Mast'r Carp.
39.*	Interlocking plant	8½ × 14	W.	Towerman.	P. A. Engr.
40.	Tools & material at interlocking plant	8½ × 14	M.	Towerman.	Mast'r Carp.
41.	Delay by block signal	7 × 5½	...	Sig. or rep. mn.	Hd. of Dept.
42.	Electric block signal report	8½ × 14	M.	Head of Dept.	P. A. Engr.
43.*	Train accidents	8½ × 14	...	Roadmaster.	"
44.	Tie inspection	5½ × 8½	D.	Tie Inspector.	"
45.	Ties forwarded (notice)	5½ × 8½	...	P. Asst. Engr.	Roadmaster.
46.	Condition of handcars taken to shop	8½ × 7	...	Shop Fore. or Trav. H. C. rep. fore.	Mast'r Carp.
47.	Handcars inspected (giving defects, &c.)	....	M.	Master Carp.	P. A. Engr.
48.	Scales tested	14 × 8½	M.	Master Carp.	P. A. Engr.
49.	Time of work on buildings	8¼ × 10½	W.	Bldg. Fore.	Heads depts.
50.	Requisitions	5¼×8½ and 8¼ × 10½	...	Hds. of Depts.	P. A. Engr.

ENGINEER DEPARTMENT.

Section No. ....(Division or Branch.)

Report of Work Done and Changes Made During Month of ....190....

This blank must be filled out and sent to Roadmaster as soon after end of month as possible. Each item must be answered in some way; if there is nothing to report, the words "Nothing Done," must be written. Section foremen will report results and changes on their sections whether made by themselves or by others. Results accomplished by extra gangs, fence gangs, and other section gangs, as well as by carpenters, telegraph linemen, or outside parties must therefore be reported by the various foremen having charge of the sections on which done. Foremen on lines having 2, 3 or 4 main tracks will show which track is referred to by writing its name in the space left for that purpose in certain items.

1. New steel rail has been laid in ....main track from Sta.......to Sta......
   " " " " " " .... " " " ...... " ......
2. 2d-hand and cut rail has been laid in........ " " " ...... " ......
   " " " " " " " .... " " " ...... " ......
3. New ballast has been put in .... " " " ...... " ......
   " " " " " .... " " " ...... " ......
4. New ditch has been dug on ....side of track from Sta......to Sta......
   " " " " " " .... " " " " " ...... " ......
5. Old ditch has been cleaned on .... " " " " " ...... " ......
   " " " " " " .... " " " " " ...... " ......
6. Stand. cross-sec. been completed on........ " " " " " ...... " ......
   " " " " " .... " " " " " ...... " ......
7. New fence has been constructed on .... " " " " " ...... " ......
   " " " " " " .... " " " " " ...... " ......
   " " " " " " .... " " " " " ...... " ......
8. Steel rail has been laid in following named side tracks: ....
9. The following new side tracks have been built and old ones extended: ....
10. The following side tracks have been taken up and shortened..........................
11. Fly rails were changed at following switches: ....
12. Frogs were changed at following switches: ....
13. Cattle-guards were renewed or repaired at following named crossings: ....
14. The following changes were made in fixed signals: ....
15. The following railway crossing frogs were changed: ....
16. New obstructions within 6 ft. of track have been put up at following places: ......
17. The following named side obstructions within 6 ft. of track have been changed or removed: ....
18. All bridges and culverts on this section are in good condition, except the following:
....
....

Remarks: ....

....Section Foreman.

(Blank No. 1.)

Monthly Report on Section Work; L. S. & M. S. Ry.

Report of Defective Steel Rails removed from Main Tracks on ________________ Division, during month of ________________ 190__

Section Foremen will report on this blank to Roadmaster all rails removed from Main Tracks for any of the causes mentioned below, or for any other failure. This will include rails disabled by wreck, but will not include rails worn out in a legitimate way after 5 years service. No side track or switch rails are to be reported hereon. Report one rail only on each line.

Removed from		Kind of Rail.				Brand.			Kind of Joint Fastening.							Cause of Removal.												
Section.	Track—North, south, east, west, middle or single main.	Cut.	Uncut.	Length, in Feet.	Weight per Yard.	Mill.	Date Made.		4-hole Fish Plate, Joint on Tie.	4-hole Fish Plate, Joint between Ties.	4-hole Angle Splice, Joint between Ties.	4-hole Angle Splice, Joint on Tie.	6-hole Angle Splice, Joint on Tie.			Broken in Two.	Cracked.	Piece broken out of Head.	Piece broken out of Flange.	Battered and Worn at End.	Dangerous, acc't of Flaw.	Burned by Engine Slipping.	Bad in Line or Surface.	Worn out on Curve.	Worn out under ordinary conditions before serving 5 years.	Was failure caused by wreck or broken wheel.	Was rail broken at Bolt Hole.	Did rail show sign of Flaw.

(Blank No. 2.)

Monthly Inventory of Tools and Equipment on .... {Branch or Division} for .... 189...

Road Masters will show only new tools in stock, the equipment (or Engineers Dep't tools on wheels) on his Division, and the total number on his territory, of the large tools marked "new and 2d hand." Second hand tools in stock or in the hands of his men are not to be included.

KIND OF TOOL		On Hand 1st	Received	Shipped	Used	On Hand ......1st.	KIND OF TOOL		On Hand ......1st.	Received	Shipped	Used	On Hand ......1st.
Axes, Chopping,	New, No. of						Dippers, Drinking	New, No. of					
" Hand,	" "						Drills, Ratchet	" "					
Adzes,	" "						" Frames	" "					
Augers	" "						" Points, 7/8"	" "					
							" " 5/8"	" "					

(Blank No. 4.)

Each Section Foreman must keep careful count of all Second-Hand Material and Scrap, received by **Removal from Track and Right of Way,** as well as that received from Road Master, and show each kind as received in the proper column. All material of every description, both new and second-hand, if fit for use, must be shown.

Monthly Inventory of New and Second-Hand Material On Sec. .... {Branch or Division.} for .... 189...

KIND OF MATERIAL.	On Hand ......1st.	RECEIVED: By Removal from Track and Right of Way.	RECEIVED: From Road Master.	Shipped.	Used.	On Hand ......1st.	KIND OF MATERIAL.		On Hand ......1st.	RECEIVED: By Removal from Track and Right of Way.	RECEIVED: From Road Master.	Shipped.	Used.	On Hand 1st
							Frogs, Spring, 4¾", L. H. 1 in 10,	New, No. of						
							Frogs, Spring, 4¾", L. H. 1 in 10,	2d Hd. "						
							Frogs, Spring, 4¾", R. H. 1 in 10.	New, "						

(Blank No. 5.)

Weekly Report of..............Gang No... ....Div'n,

for Week ending................................189......

FOR REGULAR SECTION AND FENCE GANGS ONLY.

Section and fence gang foremen will fill out these blanks on the 7th, 14th, 21st and last day of each month and forward to Road Master. Under "Remarks," should be given amount of other work done not enumerated on the blank, together with necessary explanations or additional data asked for by Road Master.

Number of men now in gang including foreman..

Total days work performed during week, per time book..

What hand and push cars are on hand?..

Have they been examined daily?..

What is their present condition?..

Have frogs and switches been daily examined and repaired?..

Has frog and switch blocking been daily examined and repaired?..

Cross ties put in main tracks..

" " " " new and old side tracks..

North main track surfaced. From sta..................to sta...................

South " " " " " .... " " ....

North " " ballasted and completed. " " .... " " ....

South " " " " " " " .... " " ....

New rail laid in..............main track. " " .... " " ....

" " " "............. " " " " .... " " ....

Cut " " "............. " " " " .... " " ....

" " " "............. " " " " .... " " ....

Feet of new ditch dug..

" " ditches cleaned..

" " cross-section made..

REMARKS:..

(Blank No. 7.)

A committee of the Roadmasters' Association of America reported in 1894 that the blank forms for maintenance of way records should be made up to suit the organization and the system of accounts in use on each road. Consequently no special recommendation could be given as to their number

Weekly Report of Section and Fence Gangs..Div'n,

For week ending..189.....

Road Masters will fill out these blanks and forward to Division Engineer on 8th, 15th, 22d and 1st day of each month.

	Number of.	Number of days work performed including laborers and foremen.
Regular section gangs.		
" **fence** "		

(Blank No. 8.)

Daily Report of Extra Gang...*Division.*

....*189*...

Extra Gang Foremen should fill out these blanks each night and forward to their superior. The distribution of labor should be taken from sheet or book on which it is kept, the object being to obtain, daily, a record of how much time is being expended on each piece of work or portion of it.

On what piece of work engaged..

No. of days work performed (Exclusive of Teams and Drivers.) ....

No. " " by Teams and Drivers..........................

Total days work performed, per time book ....

No. Flat cars of earth or gravel loaded...........Earth........Gravel........

No. Gondola " " " ....Earth........Gravel........

No. Dump " " " ....Earth........Gravel........

			UNLOADED.	WHERE UNLOADED.
No. Flat	Cars	Gravel	....	....
No. Gondola	"	"	....	....
No. Dump	"	"	....	....
No. Flat	"	Earth	....	....
No. Gondola	"	"	....	....
No. Dump	"	"	....	....

DISTRIBUTION OF LABOR.

..................days work on..

Blank No.9.

or details. It was thought that the blank forms on many roads were more complicated than necessary to secure the end desired, and often secure duplicate or insufficient information. The committee regarded the following information and forms as generally necessary for a proper record of

DAILY REPORT OF EXCAVATOR No.______

______________________*189*

Steam Shovel Engineers should fill out these blanks each night and forward to their superior.

Where located ______________________________

On what work engaged______________________________

Total days work performed, per time book ______________________

Number of Flat Cars loaded__________Kind of Material__________

" Gondola " " __________ " __________

" Dump " " __________ " __________

Total time lost______________________________

Cause of delays:______________________________

(Blank No.10.)

the maintenance of way department of any railway, and for securing the proper charges:

(A) Daily record of each trackman's work on a sub-division or on a work train, so that his time can be charged to the proper account.
(B) Daily record of material used on each track foreman's sub-division.
(C) Daily record of materials handled by work trains.
(D) Track foreman's monthly report of work done and materials used terial on hand.
(E) Work train foreman's monthly report of work done.
(F) Foreman carpenter's monthly report of all materials used and on hand and work done.

Daily Report of Work Train...*Division.*

....*189*....

Work Train Conductors should fill out these blanks each night and forward to their superior.

On what piece of work engaged..

Number of Locomotive ....

Number of days work performed, per time book.................................

			UNLOADED.	WHERE UNLOADED.
No. Flat	Cars	Gravel	....	....
No. Gondola	"	"	....	....
No. Dump	"	"	....	....
No. Flat	"	Earth	....	....
No. Gondola	"	"	....	....
No. Dump	"	"	....	....

No. Flat Cars held in service for next day's use.................................

No. Gondola Cars held in service for next day's use..........................

No. Dump " " " " " ....

(Blank No.11.)

(G) Monthly report by track foremen and foremen carpenters of tools on hand.
(H) Supervisor's or roadmaster's monthly report of all materials used and on hand, and giving the distribution.
(I) Supervisor's or roadmaster's report of periodical inventories of material on hand.
(J) Track foreman's and roadmaster's report of fires along the right-of-way.

DAILY REPORT OF EXTRA FORCE,......................................DIVISION.

....189.......

This report should be forwarded to Division Engineer daily. "Extra Men" includes all men paid on Road Master's rolls outside of those on Section and Fence Gang rolls. Each gravel pit and each piece of important work, such as a section of second track construction, change of grade, a new yard, or extensive ballasting of old main track, should be kept separate. Gangs or work trains engaged in ordinary miscellaneous work should be shown as doing such.

At What Point, or On What Piece of Work.	Days' Work Performed by Extra Men.					Excavators at Work. Numbers of	Number of Work Trains.	Locomotives, Numbers of	Cars in Service of Work Trains at End of Day.			Remarks.
	Conductors and Brakemen.	Men on Excavator Rolls.	Teamsters with Teams.	All Other Extra Men.	Total.				Flats.	Gondolas.	Dumps.	

(Blank No. 13.)

DAILY REPORT OF GRAVEL AND EARTH HANDLED,.................................DIVISION,.......... ....189...

This Report should be Forwarded to Division Engineer Daily. The material handled on each piece of Second Track, Change of Grade, or other important work, as well as in each Gravel Pit, should be Shown Separately. Gravel unloaded for ordinary main line ballasting on divisions where such ballast has been received from elsewhere, must be likewise treated.

Loaded								Unloaded or Shipped.							Remarks.
At What Point, or On What Piece of Work	By What Means, Excavator or Hand	Gravel			Earth.			On What Piece of Work, or To What Point.	Gravel			Earth.			
		Flats.	Gondolas.	Dumps.	Flats.	Gondolas.	Dumps.		Flats.	Gondolas.	Dumps.	Flats.	Gondolas.	Dumps.	

(Blank No. 15.)

Scrap on hand, ...1st, 1£0.... ....Division.

Steel rail, less than 3-ft. long.	....	gross tons.
Steel rail, 3-ft. long and over.	....	" "
Iron rail, American.	....	" "
Iron rail, English.	....	" "
Steel cap rail.	....	" "
Steel frog, switch and guard rail.	....	" "

....Roadmaster.

(Blank No. 19.)

Monthly Report of Scrap; L. S. & M. S. Ry.

NEW SIDE TRACKS CONSTRUCTED, ______________ Division ______________ 189__

AT WHAT STATION.	NAME OF TRACK.	LOCATION BY STATION STAKES.		FEET OF TRACK CONSTRUCTED.	REMARKS.
		FROM	TO		

(Blank No. 21.)

SIDE TRACKS TAKEN UP, ______________ *Division,* ______________ *189*__

AT WHAT STATION.	NAME OF TRACK.	FEET OF TRACK TAKEN UP.	KIND OF RAIL.	KIND OF SWITCH REMOVED, IF ANY.	REMARKS.

(Blank No. 22.)

NEW STEEL RAIL LAID IN MAIN TRACK FOR RENEWALS, ______________ Division, ______________ 189_

LOCATION BY STATION STAKES.		FEET OF TRACK LAID.	BRAND.			NUMBER OF RAILS LAID OF EACH LENGTH.	REMARKS.
FROM	TO		MANUFACTURE.	Month.	Year.		

(Blank No. 23.)

Road-Master's Bridge and Culvert Inspection on ______________ {Branch or Division} during ______________ 189

Having made a careful personal inspection of Bridges and Culverts on this line within... ...days of date, I find all to be in good condition, except those enumerated below.

Class and Number.	Kind of Structure.	Date of Inspection.	Condition.	REMARKS.

(Blank No. 26.)

REPORT OF BROKEN RAILS FOUND IN THE MAIN TRACK.

Whenever a broken rail is found in the main track, a report should be sent to the Principal Assistant Engineer by the Roadmaster as soon as possible after a careful investigation has been made.

About a foot of the rail on each side of the break should be cut off and stored away, properly labeled and numbered, so that the fracture may be inspected at any future time.

Date..

Time of day or night ....

By whom ....

Where located (approximate distance east or west of nearest Passenger Station)........

Brand of rail (maker and year)..

Heat mark ....

Length of rail ....

Was it a cut rail or not?..

Kind of joint fastening..

Description of break, stating how far from end of rail..

Did it occur between ties or on top of tie?..

Approximate temperature of atmosphere when found..

When had track been last patrolled?..

What is label number of stored pieces?..

Cause of break, if known..

....Roadmaster.

(Blank No. 27.)

Monthly Report of Broken Rails; L. S. & M. S. Ry.

(K) Track foreman's and roadmaster's report of stock killed.
(L) Track foreman's and roadmaster's report of broken rails.
(M) Roadmaster's report of scrap for sale.
(N) Statement covering shipment of rail and other maintenance of way or construction material.
(O) Roadmaster's report of track laid or changed.

FENCE CONSTRUCTION ON.................. Division, during ...., 190..

Locat'ns by Sta. stakes		Which side of track.	Feet.	Kind of fence.	Cost.			New or old material.	Remarks.
From	To				Labor.	Material.	Total.		
....	....	......	....	....	......	....	......	.....	....
....	....	......	....	....	......	....	......	.....	....
....	....	......	....	....	......	....	......	.....	....
....	....	......	....	....	......	....	......	.....	....
....	....	......	....	....	......	....	......	.....	....

(Blank No. 36.)

Roadmaster's Report on Fence Construction; L. S. & M. S. Ry.

WEEKLY REPORT ON CONDITION OF INTERLOCKING PLANT AT................

This blank must be carefully filled out on Saturday of each week by towerman having charge of plant, and forwarded to Principal Assistant Engineer in accordance with Rule 34 of General Instructions to Towermen, governing the operation and maintenance of interlocking plants.

What foundations have needed bracing and tamping?..............................
What stands (of any kind) are hard to keep solid on the foundations? Do the nuts work loose, or do the bolts seem to be pulling up through foundation?.........
Have any washers been put under any of the point rail feet, and are any in use now?...
What switches or signals have got out of adjustment?..............................
What levers throw too hard; do they have to be rushed past a sticking point when once started?..
What lamps are giving trouble, either by going out, burning poorly, or getting on fire? What style of make are the lamps, and what pattern burner?....................
Has any sand been used over the plant? If so, give date and time with train and engine number..
Mention here anything not specified above: ....
....

Date............................190.....

....Towerman.

(Blank No. 39.)

Interlocking Plant Report; L. S. & M. S. Ry.

REPORT OF TRAIN ACCIDENTS.

Classification ....
Train............; No. ....; Section ....; Conductor....................
Engine No. .... Engineman..
Date, ...190...... Time: ....A. M.; ....P. M.
Place ....
Main, side or private track ....
If private track give owner's name in full....................................
At switch or frog.......................; Split or stub switch....................
Trailing or facing point..
Cause ....
On curve or straight line...
If on curve, give degree of curvature........; Elevation........; Spread of gage........
Gage of track................................... ....feet ....inches.
Is engine off track?..
Damage to track...
No. of cars off track........................... ....loaded; ....empty.
Cost of repairs: Labor....$..........; Material....$..........; Total....$..........
Cost of wreckage done by Engineer Department..................................
Name of employee of Engineer Department who reported accident.................
Occupation..
Remarks: ....
....

Correct:

....

Roadmaster.

(Blank No.48.)

Train Accident Report; L. S. & M. S. Ry.

Among the most important of these reports are the weekly reports made by the section foremen, showing the details of work done on the sections. By these the roadmaster can keep in touch with the maintenance work on the whole line and see how the men are getting along, besides knowing what sections need special attention at the first opportunity. The blank may be in book form, the first page having columns for the month, day, number of men, number of hours worked, location of work (by mile and station) and about a third of the page for describing the kind of work. In the lower left-hand corner may be a space for the number of ties received, used and on hand at the end of the week and month. In the larger space for remarks are entered the dates of completing special work, and notes of materials or tools needed. Some roads, however, prefer to use

sheets, as giving space for a greater number of items, the entries being made daily from the time book. The section foremen's report sheet used on the Lake Shore & Michigan Southern Ry. is $11\frac{1}{4} \times 18$ ins., with 31 vertical columns for the time worked each day on the various items; these are followed by a column for the total amount of each item for the month, and a column of "cost," which latter is to be filled in by the roadmaster. The following is a list of the items of work in the left-hand column:

SECTION FOREMAN'S REPORT; L. S. & M. S. RY.

Distribution of Labor.............. Section............. Division............ 190....

Section foreman must charge up on this blank at close of each day the total day's work per time book. Any work done not covered below must be described clearly in one of the blank lines. It is important that these various kinds of work be charged with the labor performed on them, so that the cost over the entire road may be determined. The item "Repairs sidetracks and switches—other repairs," is to be charged with all work of repairing sidings and switches, whether in main track or elsewhere, except the ballasting and putting in new cross ties, which are to be shown separately as below. Any work done on a track or switch for which some outside party should pay, must be shown separately on a blank line. If work be done on bridges, steam railway crossings, interlocking plants, street railway crossings, station grounds, etc., the number or name should be always given, and a description of what was done.

Kind of Work Performed:

Patrolling track		......
Track watching extra, account of		......
Tightening bolts	Main track.	......
Gaging	" "	......
Changing rails	" "	......
Shimming	" "	......
Shifting ties, surfacing and lining	" "	......
Handling and distributing new cross ties for	" "	......
Putting new cross ties in	" "	......
Handling and distributing new rail and splices for	" "	......
Laying new rail in	" "	......
Surfacing and shifting ties under new rail (when laying)	" "	......
Picking up second-hand rail taken out of	" "	......
Handling and distributing second-hand and cut rail and splices for	" "	......
Laying second-hand and cut rail in	" "	......
Surfacing and shifting ties under second-hand and cut rail (when laying)	" "	......
Loading gravel for ballasting	" "	......
Unloading gravel for ballasting	" "	......
Putting new gravel ballast in	" "	......
Handling cinders for ballasting	" "	......
Putting cinder ballast in	" "	......
Cross sectioning		......
Digging new ditch		......
Cleaning old ditch		......
Scurfing and clearing up roadbed outside of yard		......
Mowing, burning and cleaning up right of way		......
Handling track scrap		......
Repairs sidetracks and switches... Gravel ballasting		......
Repairs sidetracks and switches... Cinder ballasting		......
Repairs sidetracks and switches... Putting in new cross ties.		......
Repairs sidetracks and switches... Other repairs		......
Taking up............old sidetrack		......
Scurfing and cleaning up roadbed in yards		......
Grading for new (or ext. of)............sidetrack		......
Laying and ballasting new (or ext. of)............sidetrack		......
Handling track materials and supplies		......
Railway crossing frogs		......
Railway interlocking		......
Acc't. block signals		......
Street railway crossings		......
Handling snow and ice at ....Railway crossing; interlocking (L. S. & M. S. tracks)		......
" " " " on our main tracks		......
" " " " on sidetracks and switches		......
" " " " on street, highway and farm crossings		......
" " " " on ....station platform		......
Inspecting bridges and culverts		......
Cleaning out bridges and culverts		......
" " at bridge (or culvert) No.		......

Handling and distributing material for new fence	
Building new fence along right of way	
Repairing old fence along right of way	
Repairing street, highway and farm crossings and signs	
Building new .... highway (or farm) crossing	
Cleaning up .... station grounds	
Handling car scrap	
Handling fuel for .... water station	
Handling fuel for .... station use	
Loading old ties for wood	
Handling and loading wood	
Clearing up wrecks, and assisting wrecking crews	
Repairing tracks and switches, acc't of derailments	
Fighting fire	
Helping agent transfer freight at	
Oiling windmills at	
Total days' work performed	

In preparing forms of reports for use by the foremen, it must be recognized that the men are apt to be but poorly educated and not well fitted for doing much literary work. For these reasons, the reports should be simple and plain, as complex reports inaccurately filled out are merely a waste of time, since they are practically valueless. The foremen should be required to fill in their reports with their own hands, and not have station agents or others do this, as there will be less liability to error and it will serve to educate the foremen in the proper method of keeping the reports. In some cases the foreman is left to fill in the kind of work, but as a rule there are numerous columns, the headings of which are the different classes of work, and the foreman fills in the number of hours for the particular kind of work done each day by each laborer, there being a page for each man. At the back of the book may be a page for the material received, used and on hand, the latter amount being entered in the new book at the beginning of each month. The columns are footed up at the end of each month and sent to the roadmaster.

The form of time book used by the Pennsylvania Ry. is shown herewith. The record occupies the two opposite pages of an oblong book, 8½ × 6¼ ins., having 50 double pages, and being bound in limp leather. This book, properly signed by the foreman, must be returned on the last day of each month to the supervisor, who examines it, certifies if correct, and forwards it to the office of the assistant engineer, where the check rolls are made out. The last columns—"Total Amount Due" and "Chargeable to"—are left blank by the foreman to be filled in by the supervisor. Another form of monthly time book, used by the Chicago & Northwestern Ry., is also shown. The book is upright, 8¼ × 5½ ins., with stiff paper covers and seven double pages. It is entitled "Distribution of Track Labor for Section No. ——;" the exact location of the section is entered on the cover, or if the book is used for a train, gravel pit or quarry, the name of same must be entered. On the inside of the cover are printed the following instructions to the track foremen in reference to the distribution of labor in the book:

The total number of hours worked should be entered in the first column, headed "Total Time Worked." Following this, columns are provided for distributing the labor under the different headings, and track foremen are required to enter under such headings the number of hours chargeable to each as follows:

General Repairs to Track.—Enter the time consumed in cutting and repairing rails, repairing side tracks, taking up sidings, surfacing track and all other ordinary repairs not enumerated below.

Laying Ties.—Enter the time used in taking up and disposing of old ties, and unloading, handling and laying new ties to replace those taken up.

Laying Rails.—Enter the time consumed in removing and disposing of rails from track and replacing same with other rails; also the ordinary surfacing of the track at the time the rails are laid, and loading the old rails to be sent away.

Ditching.—Enter the time used in opening, clearing, widening and perfecting ditches and drains, and cutting down or strengthening embankments.

Freshet Repairs.—Enter the time consumed in repairing damages to roadway and track caused by freshets.

Track Watchmen Necessitated by Repairs.—Enter the time of men engaged as watchmen and flagmen while repairs of track are in progress and rendered necessary by such repairs.

Ballasting.—Enter the work done in gravel pits, hauling gravel and stone for use in track, quarrying and breaking stone for ballast, raising and repairing track with ballast. (Note.—Gravel train conductors and foremen of gravel pits and quarries must, in all cases, state on what division, subdivision and section of road the gravel or ballast is to be used, so that the expenses may be properly charged.)

Clearing Track of Snow, and Cutting Weeds, Brush and Grass.—This includes clearing same from the roadway and track, etc., and mowing and burning weeds, brush and grass inside of fences.

Repairs of Fences, Road Crossings and Signs.—Enter the time consumed in repairing and rebuilding fences, road crossings and signs.

Flagmen.—Enter the time of men engaged as flagmen at crossings.

Repairs of Bridges and Culverts.—Enter the time consumed in repairing or strengthening bridges and culverts.

Bridge Watchmen Necessitated by Repairs.—Enter the time of men engaged as watchmen and flagmen while repairs of bridges or culverts are in progress and rendered necessary by such repairs.

Repairs of Cattleguards.—Enter the time consumed in repairing and renewing cattleguards.

Reloading Freight, Getting Cars on Track, Etc.—This account includes time occupied in watching and reloading freight into cars and getting cars on the track when wrecked or disabled. It also includes time consumed in picking up lumber or other freight lost from cars along the line. (Give particulars in each case.)

Station Labor.—Enter in this column labor assisting at stations in loading and unloading freight or performing other station labor, such as attending to switches. (Give name of station in each instance, and kind of work done.)

Maintaining Telegraph.—Enter the time devoted to repairing or looking after telegraph lines.

Construction of Sidings.—Enter the time consumed in grading and laying new sidetracks and lengthening and extending old sidings.

Remarks.—Enter in this column such items or charges as do not properly belong under the headings provided, as specified above, stating in every case the nature of the work and where it was done; also if a time ticket has been given, enter the particulars in this column.

The time of track foremen, conductors of gravel trains and foremen of gravel pits should be distributed herein each day in the same manner as track laborers.

Enter the distribution of labor in this book in a plain, legible manner, at the close of each day's work, and oftener when necessary. At the close of the month add up each column and enter the footings at the bottom of the column, opposite the word "Totals," being careful to see that the footings of all the distribution columns (when added together) agree with the footings of the columns headed "Total Time Worked."

This book must be sent forward promptly, as directed, on the night of the last day of the month.

Instruction Books.—The work of the roadmasters and section foremen, who are the men in actual charge of the track, carries a considerable responsibility, and the most thorough means should be taken to keep these men fully informed as to their duties, and to impress upon them that the safe and proper condition of the track is the first and most important consideration. An excellent plan is to issue "instruction books," similar to those already in use on many roads. For a road starting to adopt this plan, the books should at first be small pamphlets, so as not to incur much expense, and after they have been in service for a sufficient time to become well known and well used, opinions and suggestions should be invited from time to time from the men on the road and from officers of other roads in order that improvements may be made by eliminations, alterations and additions, so as to embody the best results of actual experience. A handy book can then be made up for permanent use. The matter should be clearly and concisely written (care being taken to avoid ambiguous phraseology, involved sentences or words not commonly used), so as to be readily understood, and the use of diagrams will add to the usefulness of the book. It should be clearly printed on strong paper, and strongly bound. A few stubs between the leaves will allow of pasting in additional leaves issued from time to time. The illustrations should preferably be on the pages of the book, or at any rate on sheets not folded more than once or twice, as large folding sheets are awkward to handle and are liable to be very soon torn. Special instructions should be given to the section foremen when any important improvements are to be carried out or new devices tested.

The character of the instructions and regulations to be given in these books has been outlined in the chapter on "Organization." The latest edition of the "Rules of the Road Department" of the Illinois Central Ry., issued in 1899, is a book of 62 pages, bound in cloth, $4\frac{1}{2} \times 7$ ins., the pages having rounded corners to prevent "dog's ears." First come the rules for section foremen as to "Ditching," "Ballast," "Cross Ties," "Rails," "Curves," "Switches," "Watching," "Material," "Accidents," "Hand and Push Cars," "Water Stations," "Policing," "Reports," and "General Rules." Then come Rules for Conductors of Construction Trains, Rules for Road Supervisors, and Rules and Instructions for the Bridge Department. There are also tables of curve elevation and bills of switch timbers. The illustrations are printed on the pages of the book and include various roadbed cross-sections, switches, frog guard rails, position of spikes, and diagrams of slip switches with rigid frogs and movable points. The Southern Pacific Ry. book is more bulky, and has a number of folding plates.

Requisitions.—One of the most troublesome details in railway service is the handling of requisitions for supplies, and much friction and expense are too frequently caused by a lack of harmony between the executive officers and the accounting officers. Requisitions for ties and such material are not infrequently disallowed or cut down by some higher official who has no idea of the actual requirements, but who simply thinks that requisitions are too large, or that economies must be observed, or who entertains the erroneous impression that every dollar cut from a requisition is a dollar saved to the company. Such officials need to be

educated in the principles of railway economics until they realize the relations between expenditures and the results obtained therefrom, and understand that large expenditures may in some cases tend to real economy of operation. The wide cutting down of requisitions is very discouraging to a man who has carefully and honestly prepared his requisition to meet actual needs. Such a practice cannot but result in carelessness

ACCOUNT OF TIME WORKED for the Pennsylvania Railroad Company during the

NAMES.	HOW EMPLOYED.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1																			
2																			
20																			

I certify that the persons to whose names time is affixed have been diligently employed, during the time specified, in the service of the Pennsylvania Railroad Company.

Foreman.

in estimating, or in the exaggeration of the amounts called for, so that the "cut" requisition will still meet requirements. The roadmaster, engineer or superintendent should inform himself as to the financial conditions of the company, and its business outlook. He should prepare his estimates with these conditions in view, and then be prepared to stand by his estimate or requisition and show that it is reasonable and necessary. On the other hand, the accounting officers should recognize that the executive men are in better position to know what are the needs of the road for

[SEE NEXT PAGE.]

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WORK Performed in the Month

Occupation____________________

DATE.	Total Time Worked.	"REPAIRS OF ROADWAY AND TRACK."								"Repairs of Fences."
		General Repairs Track.	Laying Ties.	Laying Rails.	Ditching.	Freshet Repairs.	Track Watchmen necessitated by repairs.	Ballasting.	Clearing Track of Snow and Cutting Weeds and Grass.	Repairing Fences, Road Crossings and Signs.
1										
2										
3										
31										
Total No of Hours,										
Total Am't of Wages,										

its proper and economical maintenance and operation, and should be prepared to authorize the requisitions, or to at least consult with the men submitting them before making any changes. These men are thus made responsible for their requisitions, and should be held strictly accountable for them. Such a system will conduce to harmonious working of the entire

operating force, from president and manager to roadmaster and foreman, and will result in the truest economy in operation and maintenance.

Cost of Railway Maintenance Work.—This is so large a proportion of the total cost of operation that it is most important, in the interests of economy, that full and accurate records should be kept of the deails of work done, the material consumed, and the cost of the various items of work

Month of ______ 189__													Time Worked.		Rate of Pay.		Total Am't Due.		______ ______ DIVISION. Subdiv. No. ______	
19	20	21	22	23	24	25	26	27	28	29	30	31	Mo.	Hrs.	Dolls	Cts.	Dolls	Cts.	CHARGEABLE TO	
Examined and found correct,								Supervisor					Total Amount, $						Total Amount of Check Roll, $	

and material. As such records must be based mainly on the returns and reports of the section foreman, it is essential that such returns and reports should be so designed as to give all necessary information with the least possible work on the part of these men, and with the lowest possible chance for error on their part. This matter has been dealt with very clearly by Mr. Marshall M. Kirkman, Vice-President of the Chicago & Northwestern Ry., in his pamphlet on "The Track Accounts of Railways." His plan is, in brief, to have the final records attained in two distribution

[SEE PRECEDING PAGE.]

of ______ 189__, By ______

Rate, $______ per ______

Flagmen.	"Watchmen."	"Repairs of Bridges and Culverts."		"Repairs of Cattle Gds."	"Laborers."		"Maintaining Telegraph."	"Construction of Sidings."	
Flagmen at Crossings.	Bridge and Track Watchmen.	Repairing Bridges and Culverts.	Bridge Watchmen Necessitated by Repairs.	Repairing Cattle Guards.	Reloading Cars, Getting Cars on Track, etc.	Station Labor.	Repairing Telegraph.	New Side Tracks.	REMARKS.
									Grand Total, $______

books or statements, one being for labor and the other for material. These are posted up by the superintendent monthly from the foremen's books, and show all track expenditures, and the accounts to which such expenditures are properly chargeable. At the general office a "track material" account is kept with each division superintendent. In the superintendent's

book the average cost per mile for repairs of track and roadway is obtained by summing up the total number of hours worked on each subdivision, and taking a full day's work for each man for the entire month. Particulars of the distribution of cost for the various items of work are given in the instruction books of some railways, and in Mr. McHenry's "Rules and Instructions for Location, Construction and Maintenance; Northern Pacific Ry." The scheme of distribution is based upon that drawn up by the Interstate Commerce Commission and issued to the railways for instruction in the preparation of their annual reports to the Commission.

During construction and maintenance, careful notes should be made and records kept and tabulated to show the work done, time occupied, tools and materials used, items of cost, etc. The regular reports should show the number of men engaged on each particular item and class of work, and the character and amount of materials used. All work of this kind, which puts figures on record and enables comparisons to be made, and the relations between work, expenditure and results to be comprehended, tends toward the improvement of work and methods. Proper financial accounts of all expenditures for maintenance and renewals and betterments should also be made. In the annual estimates, some railways allow to each division a certain amount for track work, but the appropriation for betterments or construction should be entirely separate from that for maintenance.

The lack of complete and uniform records of the cost of various items of work is a drawback to the economical administration of the roadway department. In 1897, the author pointed out in an address delivered before the Roadmasters' Association of America, that if statistics were kept of the cost of the various items of work on the track they would furnish most valuable information. As a matter of fact, there is great uncertainty both as to the cost of work and as to the amount of labor involved in the work. The importance of this matter may be recognized when it is understood that a roadmaster may have charge of the expenditure of $60,000 to $100,000 per year, as already explained. The mechanical and operating departments keep itemized records, and the annual reports of railways show the amounts of coal, water and oil consumed per mile run by the engine, and the expenses for wages and repairs per mile run; also the cost of service per ton-mile, per passenger-mile and per train-mile, etc. These are compared from year to year, so that it can be seen at once how the traffic and operating conditions have varied and how the cost of handling the traffic has varied. In the same way it should be possible to know the cost of such items as the following: (1) Cost of ties in the track (including first cost, transportation, handling, distribution, putting in, tamping and cleaning up); (2) Average cost per mile per year for tie and rail renewals, for ballast and ballasting, etc.; (3) The cost of switch work, maintenance of joints, etc.; (4) The average life, wear and cost of rails, spikes, bolts, frogs, etc.; (5) Cost of operating work trains and gravel trains. In very many cases there is no record of track and roadway expenditures beyond a general statement as to the quantities of rails, ties and ballast laid, with lump sums of the expenditures. More detailed records are kept by some railway officers, but they are not systematic or uniform.

This is a matter which has a most important relation to the economy

of track work and the general operation of the road. If properly planned and carried out for a few years the records may show that expensive ties (including cost of preservative processes and tie-plates) may be really more economical than cheap ties, by reason of their greater life, thus giving a lower cost per year. The records may also show that certain cheap rails are really less economical than more expensive but better made rails, by reason of their shorter life and poorer wearing qualities. They may also show, in the general cost per mile of track, the false economy of laying new rails on old worn out ties, the same rails showing a shorter life and a greater total cost for maintenance of track under such conditions than when laid on new ties. These are questions of economics, for it must be understood that merely cutting down expenditures is not necessarily an economy, and it may be a wiser policy to make a large outlay at one time and thus reduce the cost of maintenance for several years, than to distribute the expenditure in small sums, with the result of having a continual high charge for maintenance. The work of keeping such records will seem somewhat complicated at first, but after a few years it would become crystallized into a uniform standard practice, like much of the statistical work of the mechanical and traffic departments, so that extremely valuable records could be kept with very little trouble or cost. If the railway managing officers more generally realized the importance of the expenditures on track, both directly as cash expenditures and indirectly in their influence upon traffic and other expenses, they would demand a more detailed accounting of these expenditures and their results.

APPENDIX NO. 1.

STANDARDS OF TRACK CONSTRUCTION.

In the earlier days of American railways there was great diversity of practice in design of material and methods of work, due in part to the lack of means of interchange of knowledge and in part to the general idea that each man should impress his individuality upon his work by the use of devices or methods different from those employed by other men. With the advance of technical knowledge and the means of widely disseminating this knowledge, there has been in track work, as in other branches of railway and engineering work, a decided tendency towards the adoption of standards and uniformity in materials and methods. The first edition of this book contained tabular statements showing the standard practice of track construction then in force on some fifty railways in the United States. For this second edition, new tables, on a more extended plan, have been prepared, showing the standards of construction in 1900. Since the first set of tables was prepared, considerable changes have been made, and in certain respects there has been a decided increase in the adoption of uniform standards to supersede individual ideas and preferences. It will, of course, be understood that the standards described, and which were officially stated to the writer by the chief engineers of the various lines, do not represent the actual construction on the entire mileage of these lines. They represent, however, the style of construction which is now the adopted standard in each case, and which is therefore gradually replacing other older and lighter materials and track construction.

Taking the rails as the first item for consideration, the extent to which the type of section recommended by the rail committee of the American Society of Civil Engineers has been adopted is very striking. About 60% of the railways included in the list (including the two great Canadian systems) have adopted these sections as their standard. The total mileage of the railways on the list is about 120,000 miles, of which 75% is represented by the lines which have adopted the Am. Soc. C. E. section. This, of course, does not mean that rails of this section are actually laid on any such mileage as yet, but that it is the adopted standard which is already laid to a greater or less extent and is being used for all new work and renewals. Of the other sections in use, many (including those of the Dudley type) are based on the principles underlying the design of the Am. Soc. C. E. section, and one of the most important features of all these sections is the use of a comparatively broad and shallow head with sharp top corners. The Pennsylvania Ry. is almost the only important railway which still adheres to the old-fashioned section having a thick head with corners of large radius. Many minor roads use rails of this latter type, but the general tendency on such roads also is to purchase new rails of the Am. Soc. C. E. type. Most of the main lines have rails of 75 and 80 lbs. per yd., at least. Several railways are using rails 60 ft. in length in special cases, but none have adopted this as standard, while the Lehigh Valley Ry. and Philadel-

phia & Reading Ry. have 45-ft. rails, though the standard length is 30 ft. Rails 33 ft. long are now standard on eight railways on the list.

In rail fastenings, the showing is distinctly unsatisfactory, there being no change from the old spike, whose deficiencies (especially for track carrying heavy traffic) are well and widely recognized. Spikes of improved manufacture, having sharp points or cutting edges, and clean, smooth surfaces for the shank, are being somewhat extensively used, but apart from this the rail fastening remains practically as it was 20 or 50 years ago. The usual size of the spike is 9-16-in. square, 5½ ins. long under the head, and 6 ins. over all. The interlocking bolt and other bolt fastenings appear to be very little used now, even on bridge floors. Only one road is experimenting with screw spikes, while two others have abandoned them after some trials. What is now needed is a fastening which will hold the rail rigidly to the tie, and we might learn much in this respect from European practice, where the screw spike is a standard device for track laid with T-rails.

In regard to rail joints, the extent of track laid with suspended and broken joints far exceeds that laid with supported joints and square joints. Many roads are using various forms of bridge joints, and a few have adopted such a form as standard, but in most cases they are regarded mainly as experimental or incidental. Only three roads report the three-tie joint as standard, and only eight report the supported joint. As to the practice regarding square or broken joints, the latter is now almost universally followed. Only six roads still adhere to the former, while two use both systems on different parts of their lines, and four lay their rails with square joints on tangents and broken joints on curves. The length of splice bars shows a tendency to decrease, and there are now very few of more than 36 ins. As between four-bolt and six-bolt joints, the railways are almost equally divided, the length of splice bars ranging from 20 to 26 ins. for the former and 26 to 42 ins. for the latter. The latest splice bars for the 100-lb. rails of the Pennsylvania Ry. are 30 ins. long, instead of 34 ins., as formerly. The Union Pacific Ry. is also proposing to adopt a 29-in. bar with six bolts. It is evident that close spacing of the bolts and a shortening of the joint as a whole are now much more generally approved than they were some years ago. Several railways use a 6-in. spacing for the bolts, and a few go as far as 7 or 8 ins., but beyond this the only example is the 9-in. outer spacing of the six-bolt joints of the Illinois Central Ry. On the other hand, the closest spacing is 3⅜ ins. and 4 ins. As to the track bolts, the diameter is almost universally ¾-in., or ⅞-in., though the Grand Trunk Ry. and the Pennsylvania Ry. have adopted a 1-in. bolt, the latter road using this size for 100-lb. rails only. Square nuts are used on about 75% of the lines and hexagonal nuts on the others. Many use the grip-thread bolts, with nuts automatically locked, but where ordinary bolts are used, spiral washers or nutlocks of various makes are usually applied.

The returns as to the ties used admit of but little summarizing, but the author has been careful to show in most cases the sources from which the different kinds of timbers are obtained. Records of this kind are usually classified simply by the kinds of timber, but this is not sufficient for accurate records of the life and economy of ties. Fof instance, it will be seen that oak from the south and southwest has a life of 6 to 7 years, while oak

from the northern part of the country has a life of 10 to 14 years. The most general length is 8 ft., but very many roads adopt 8½ ft., while on southern lines a length of 9 ft. is common. The usual number of ties per 30-ft. rail is from 16 to 18, though the Grand Trunk Ry. uses as many as 19 and the Pennsylvania Ry. uses only 14 to 16. The cost is very variable, depending upon the quality of the timber and the cost of transportation. Thus, oak ties range from 25 to 70 cts.; cedar, 22 to 25 cts., and yellow pine, 28 to 70 cts. The Mexican Interoceanic Ry. (3 ft. 6 ins. gage) is using English steel ties at $2.25 each (Mexican money), with an estimated life of 30 years; and also ties of Australian jarrah wood at $2 each (Mexican money), with a guaranteed life of 15 years. The showing as to the use of ties treated by preservative processes is not as good as it should be, in view of the well proved advantages and economy of these ties. It seems probable, however, that in a few years these advantages, together with the increased prices of green or untreated ties, will lead to a much more general adoption of treated ties. On the other hand, steel tie-plates continue to be very generally used. Only three roads report that these plates are not used. Of the others, some use them only on curves, or only on soft ties (sometimes on all ties and sometimes on alternate ties), while others use them much more generally. One road, the Kansas City, Fort Scott & Memphis Ry., reports that their use has been discontinued, except on bad curves. The majority of these used are of the flanged type, of different makes. The claw pattern is represented only by one make, and the Pennsylvania Ry. still uses some flat plates, which are obsolete nearly everywhere else.

Gravel ballast, including all the various qualities which that term covers, is probably used more than any other material, although stone ranks probably a close second to first-class gravel. Slag is used on many roads, and burnt clay is quite common on western railways.

Coming now to the consideration of frogs and switches, we find the bolted frog in very general favor. In several cases a combination type of frog is approved, having the rails bolted or clamped together (using the ordinary form of flange filler) and riveted to a base plate. This makes a very substantial construction to withstand the effects of heavy traffic. Spring-rail frogs are almost universally used in main line turnouts, only four or five roads still continuing to discountenance this type. Presumably the objections are mainly on the ground of greater safety with rigid frogs, but this objection will hardly hold good in the light of the very extensive experience with spring-rail frogs under the fastest and heaviest classes of traffic.

The split switch is now practically universal in main track work, though a few roads still adhere to the Wharton switch as a standard. The Canadian Pacific Ry. has adopted the MacPherson switch as its standard. The split switch is also very commonly used in yard tracks, where, however, the stub switch is still frequently to be met with, even on roads where its use would hardly be expected. The most common length of switch rail for split switches is 15 ft., while several roads use 18 ft. Lengths of 19¼, 20, 21, 24, 28 and 30 ft. are also reported, the latter being used by the Cleveland, Cincinnati, Chicago & St. Louis Ry. for switches at the ends of double track sections. Lengths of 10 to 15 ft. are usually employed for yard switches. The practice as to the use of rigid or automatic switchstands seems about equally divided, except that in many cases the switchstands are locked so as to

be rigid when set for the main track. In other words, a main line train can safely trail through a switch left set for the siding, but a train on the siding cannot trail through a switch set for the main track. The use of a spring in the switch rod, as in the Lorenz switch, is standard on only two of the railways in the list. On many important roads the main line turnouts are protected by distant signals, especially in cases where owing to a curve or obstruction the switch target cannot be seen at a distance by the engineman of an approaching train. The use of guard rails on curves is more common on the sharp curves in yard tracks and sidings than on main track, and the practice is very diverse. They are used on all curves sharper than 10° or 12° on some lines, and 20° to 25° on others. The width of flangeway ranges from $1\frac{3}{4}$ ins. plus the amount of widening of gage on the curve, to $2\frac{1}{8}$ and 3 ins., and even 5 ins.

Taken as a whole, the standards described in the tables show that the principal main lines at least have a sufficiently substantial form of track construction for the high-speed passenger trains and the enormously heavy freight trains which are now such a feature of American railway service. On many of the less important lines the construction is equally good. It is most desirable, however, that the improved character of construction should be extended much more rapidly over the entire railway system than is now being done.

Note.—Canadian Pacific Ry.—Later returns from this road revise the information given in the tables as follows: Spikes: the Goldie is standard. Rail joints, suspended, with Bonzano splices; rails laid with square joints on tangents and broken joints on curves; splice bars weigh 76 lbs. per pair for 80-lb. rails and 100 lbs. for 100-lb. rails; track bolts, $\frac{7}{8} \times 4\frac{1}{2}$ ins. for 80-lb. and $1 \times 5\frac{1}{4}$ ins. for 100-lb. rails. Nut locks are of the plate type. Ties: Average life, 8 years for tamarack and Douglas fir, 6 years for hemlock; spruce not used; width not less than 6 ins. Tie-Plates: Various types; Glendon, $\frac{1}{4} \times 5 \times 8\frac{1}{4}$ ins.; adopted for 80-lb. rails. Frogs: The Eureka spring-rail frog and MacPherson frog substitute are standard. Switches: The MacPherson and the split switch are standard; switch rails, 15 ft. long for 80-lb. rails, 18 ft. for 100-lb. rails; rigid and automatic switchstands are used.

APPENDIX NO. 2.

SPEED OF TRAINS.

Miles per hour.	Distance run in 1 sec., ft.	Time for running 1 mile. mins.	secs.	Miles per hour.	Distance run in 1 sec., ft.	Time for running 1 mile. mins.	secs.	Miles per hour.	Distance run in 1 sec., ft.	Time for running 1 mile. mins.	secs.
1	1.47	60	0	36	52.80	1	40	58	85.07	1	2
5	7.33	12	0	38	55.73	1	35	60	88.00	1	0
10	14.67	6	0	40	58.67	1	30	65	95.33	0	55
12	17.60	5	0	42	61.60	1	26	70	102.67	0	51
15	22.00	4	0	44	64.53	1	22	75	110.00	0	48
18	26.40	3	20	46	67.47	1	18	80	117.33	0	45
20	29.33	3	0	48	70.40	1	15	85	124.67	0	42
25	36.67	2	24	50	73.33	1	12	90	132.00	0	40
30	44.40	2	0	52	76.27	1	9	95	139.35	0	38
32	46.93	1	53	54	79.20	1	7	100	146.66	0	36
34	49.87	1	46	56	82.13	1	4				

STANDARDS OF TRACK CONSTRUCTION.

Tables I., II. and III., referred to in Appendix I., are shown on the folded sheets which are bound in between this leaf and the index.

Table I., Standards for Rails, Fastenings, and Joints;

Table II., Standards for Ties, Tie-Plates, and Ballast;

Table III., Standards for Frogs, Switches, etc.

The Note to Appendix I., giving corrected information as to the standards of the Canadian Pacific Ry., should be read in connection with the information as to those standards given in the tables.

Nuts.	Nut Locks.	Patented or Special Joints used.	
Square Square	None None	A few experimental	1
Square	None (Harvey grip. th. bolt)	Continuous	2
Square	Excelsior	None	3
Hexagon	Excelsior on Weber, none on contin.	Weber and Continuous	4
Square	None (Harvey grip. th. bolts)	None	5
Hexagon	Verona	None	6
Hexagon	National and Verona Tail	Continuous	7
Square	Various	Bonzano is standard	8
Square	Verona	Continuous	9
Square	None	Continuous	10
Square	None	None	11
Square	... .	None in gen. use	12
Square	Verona	None	13
Square	None	None	14
Square	Verona	None	15
Hexagon	Verona	Continuous	16
Square	Ver. tail	Continuous	17
Hexagon Square	Harvey Verona	Weber and Continuous	18
Square	Nat. and Ver.	Few experimental	19
Square	American	Continuous	20
Square	Verona	... .	21
Square	Verona	None	22
Square	National	Continuous is standard	23
Square	Verona	None	24
Hexagon	None	. ...	25
Square	Verona	None	26
Square	None	Web., Cont. & Sellers	27
Square	Verona	Continuous	28
Square	None	None	29
Hexagon	National	None generally	30
Square	Verona	Exper. only	31
Square	None	Torrey	32
Square	Ver. on old blts	Continuous	33
1½-in. sq.	Verona	None	34
Square	None	Continuous	35
Square	National	Weber	36
Square	None	....	37
Square	Ideal nut	Only experimental	38
Hexagon	Excelsior	None	39
Square	Nat. and Ver.	Exper. only	40
Hexagon	Verona	Trial only	41
Hexagon	Verona	Barschall, Fisher & Heath	42
Square	Excelsior	None	43
Hexagon	Ver. and Nat.	None	44
Square	National	None adopted	45
Square	National	Continuous (standard) and Weber	46
Square	None	Continuous and Weber	47
Sq. 1¾-in.	Verona	Bonzano	48
Square	Ver. and Am.	Web., Cont., Bonz.	49
Hexagon	Various	None	50
Square	Verona	None	51
Square	None	None	52
Square	National	None	53
Hexagon	National	None	54

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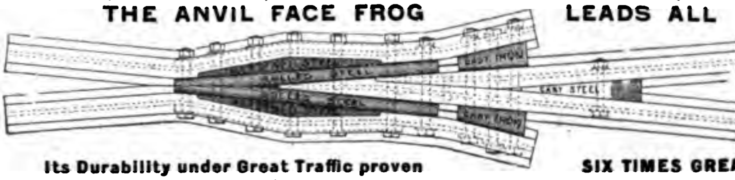

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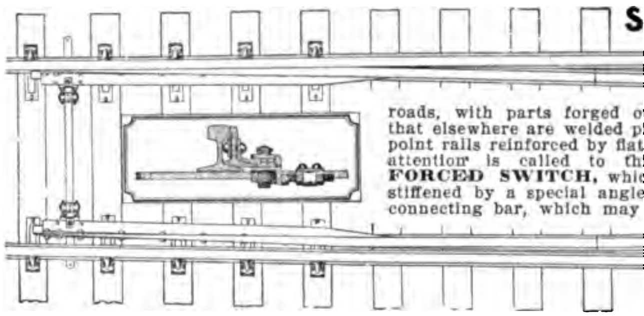

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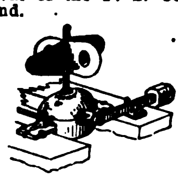

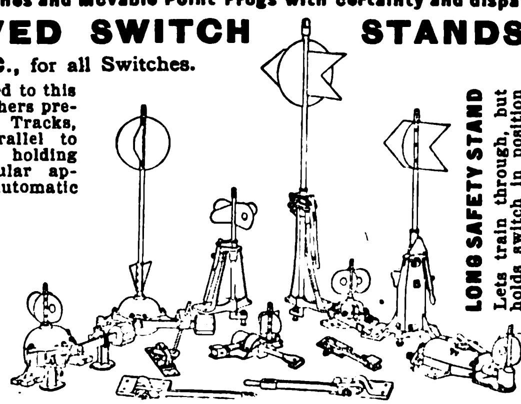

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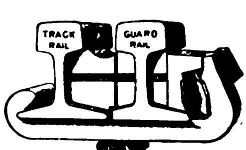

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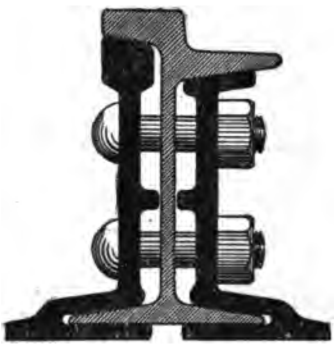

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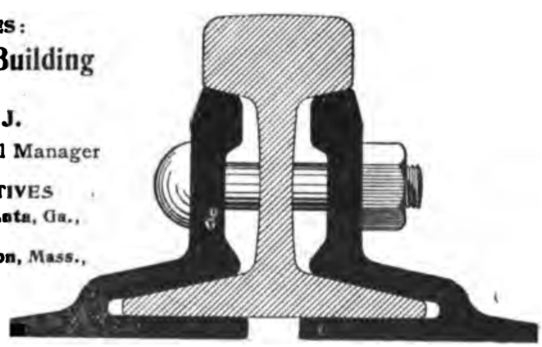

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